DOCUMENT RESUME

ED 071 261 EC 050 869

AUTHOR	Cook, Ann C. N.; Hannaford, Alonzo E.
TITLE	The Ability of Color-Vision Defective and Color-Normal Early Elementary and Junior High Students to Utilize Color. Final Report.
INSTITUTION	Western Michigan Univ., Kalamazoo. School of Education.
SPONS AGENCY	National Center for Educational Research and Development (DHEW/OE), Washington, D.C. Regional Research Program.
BUREAU NO	BR-1-E-143
PUB DATE	Nov 72
GRANT	OEG-5-71-0076(509)
NOTE	92p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Classification; Color; Elementary School Students; *Exceptional Child Education; *Identification; *Incidence; Junior High School Students; Kindergarten Children; Test Validity; Vision Tests; *Visually Handicapped; Visual Perception
IDENTIFIERS	*Color Blindness

ABSTRACT

The investigation was undertaken to obtain data on the number of kindergarten, second, and seventh grade Ss classified as having color vision defects by the American Optical-Hardy, Rand, Rittler Test (AO-HRR) and two tests by S. Ishihara. Also studied was the ability of color vision defective and color normal Ss to utilize color as measured by the Farnsworth Panel D-15 Test and the Dvorine Nomenclature Test. A single administration of the AO-HRR resulted in abnormally high percentages of Ss being identified as color vision defective. The AO-HRR classification of strong identified Ss at all grade levels who had problems utilizing color. Using the more stringent criterion of consistent failure on the AO-HRR and the two Ishihara tests, the percentages of Ss found to be color vision defective were lower than generally quoted in the literature, but approximately the same as cited for some school populations. A total of 2,476 Ss received initial testing, and 38 were found to be color vision defective using the three tests. A similar number of color vision normal Ss were selected as a comparison group. It was concluded that a factor or factors other than color vision are assessed by the AO-HRR Test when the published criteria are used with younger populations, that Ss who consistently manifest a color vision defect can vary in their ability to utilize color, and that Caucasian males manifested a significantly higher proportion of color vision defects than black males. (Author)

Final Report

Project No. 1-E-143
Grant No. OEG-5-71-0076(509)

Ann C.N. Cook
Dr. Alonzo E. Hannaford
Department of Special Education
Western Michigan University
Kalamazoo, Michigan 49001

THE ABILITY OF COLOR-VISION DEFECTIVE AND COLOR-NORMAL EARLY ELEMENTARY AND JUNIOR HIGH STUDENTS TO UTILIZE COLOR

November, 1972

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

ABSTRACT

This investigation was undertaken to provide data relative to the number of kindergarten, second, and seventh grade subjects classified as having color-vision defects by various criteria. In addition, the ability of color-vision defective and color normal subjects to utilize color as measured by the Farnsworth Panel D-15 Test and the Dvorine Nomenclature Test was studied.

The use of a single administration of the American Optical-HRR Test (AO-HRR) resulted in abnormally high percentages of subjects being identified as color-vision defective. The AO-HRR classification of "strong", identified subjects at all grade levels who had problems utilizing color. Using the more stringent criterion of consistent failure on the AO-HRR and the two Ishihara tests, the percentages of subjects found to be color-vision defective were lower than generally quoted in the literature; but approximately the same as cited for some school populations.

A total of 2,476 subjects received initial testing; 38 were found to be color-vision defective using the three tests. A similar number of color-vision normal subjects was selected as a comparison group.

It was concluded that 1) a factor or factors other than color-vision are assessed by the AO-HRR Test when the published criteria are used with younger populations, 2) subjects who consistently manifest a color-vision defect can vary in their ability to utilize color and 3) Caucasian males manifested a significantly higher proportion of color-vision defects than the Black males.

Final Report

Project No. 1-E-143
Grant No. OEG-5-71-0076(509)

THE ABILITY OF COLOR-VISION DEFECTIVE AND COLOR-NORMAL EARLY ELEMENTARY AND JUNIOR HIGH STUDENTS TO UTILIZE COLOR

Ann C.N. Cook

Dr. Alonzo E. Hannaford

Western Michigan University

Kalamazoo, Michigan

November 14, 1972

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
National Center for Educational Research and Development

ACKNOWLEDGEMENTS

Carrying out this research project would not have been possible without the assistance of many helpful people including members of the faculty and staff of Western Michigan University, opthalmologists, optometrists, physicians, educators and nurses who gave so generously of their time and talents.

Dr. James MacVicar provided insight, guidance and direction at many points along the way. The Grand Rapids School Nurses, under the direction of Miss Ruth Jubb, played a most vital role as examiners in this project. Dr. Stanley Robin, Dr. Charles Keely, Dr. James Bosco, Gordon Williams and Emery Freeman of the Grand Rapids Public Schools - Western Michigan Center for Educational Studies helpfully assisted in the development of this study and in coordinating logistical aspects so necessary for carrying out the project. Foster Buchtel, Michael Walters and Reeva Campagnano of Research Services were extremely helpful throughout the study. The Educational Resources Center of Western Michigan University, under the direction of Dr. Neil Schoenhals and Fred Brail, provided equipment and many special talents; while Mary Frances Fenton's graphic work played an important part in the training sessions and program development. Appreciation must also go to the Vision Section of the Michigan Department of Health.

Finally, the principal investigator would like to express special appreciation to Mary Ebey, Dr. William Rye, Dr. Gordon Heath, Dr. Dan Frew, Dr. Thomas Mathews, Dr. Donald Prang, to the Special Education Staff, to Dr. Alonzo Hannaford's family, to the members of the Cook family, and to all the others too numerous to mention whose assistance, understanding, and helpful encouragement made the completion of this project possible.

TABLE OF CONTENTS

APPENDIXES

LIST OF TABLES

Table

Page

CHAPTER 1---INTRODUCTION

Problem

The ability to utilize color plays a critical role in the educational and social development of children. Educational, vocational, and many other essential activities are strongly dependent upon the accurate perception of colors. In our highly color-oriented society, the child is taught by color-coded materials; the worker is instructed and guided by color codes in industry; the driver is cued by colored instructions, etc. Unfortunately, a child may have either defective color-vision without realizing it and without those around him realizing it, or he may be "color-ignorant" and have color-vision which is normal but may mistakenly believe he is "color-blind." Early detection of defective color-vision can play an irreplaceable part in the compensatory education of those with color-vision defects and prior miseducation in color recognition.

Studies (e.g. Ref. 1 through 5) indicate that color is an important factor in many elementary reading texts, arithmetic texts, remedial and special education materials, etc. The color name is often essential for: (1) understanding of a skill or concept; (2) understanding directions which are being given; (3) understanding or development of a skill or concept or (4) to enhance the visual image.[3]

Elementary teachers can usually list many ways color is used in the classroom, e.g., Cuisenaire Rods, Words in Color, Sullivan Programmed Primer, games, Frostig Perceptual Program, teacher-made devices to teach concepts, art projects and audiovisual aids (Appendix I).

When using material of this type, children may have problems with colors for different reasons, depending upon whether they are color-ignorant or whether they possess color-vision defects. Color-ignorant individuals have never learned the correct names for colors; they may have erroneously been told that they are color-blind and, believing this, have not bothered to learn colors. The child with a color-vision defect can have one of several types of color problems which may be of varying degrees: totally color-blind (sees the world in shades of black and white); red and green deficiencies (mild, medium, strong); or blue-yellow defects (mild, medium, strong).

A color-vision screening test which takes three to five minutes (American Optical H-R-R Pseudoisochromatic plates [AO-HRR]) can usually indicate if a child is color-ignorant or if he had a color-vision defect. Some children with color-vision defects can utilize color, some cannot. Finding out whether or not a color-vision

defective child can utilize color effectively can be very important to the student's education, personal adjustment, and choice of vocation.

Objectives

The objective of this study was to develop and demonstrate a reliable system of identifying those children who have color-vision defects and those who are color-ignorant, and to determine what percentage of the student population has these problems and to what degree. Early diagnosis can mean that avoidable negative experience in education may be eliminated and the imposition of psychological barriers to learning reduced.

Review of the Literature

The Importance of Early Detection

Thuline,[1] Lampe,[2] Wildman,[9] and Linksz[4] have indicated that even though color-vision defects may be neither curable nor preventable, it is an important duty of the pediatrician and the school physician to assess and determine whether or not color-vision is normal.

Children with color-vision defects can be helped to utilize color in different ways. It is suggested that for many reasons this type of training should begin when the child is as young as possible,[4,10] making early detection important.

Educational Aspects

At the present time children in the first year of school need to be able to utilize color.[1-5, 10,11] Prater found that the results of interviews conducted demonstrated the confusion experienced by a first-year pupil with deficiency in color-vision (Ref. 3, p. 93).

Betts[5] noted that the ability to discriminate between colors is of concern to many teachers because of its relationship to reading activities. About four or five percent of the boys are color-blind and about one percent or less of the girls are so handicapped. Although color-blindness may be total, it is more likely to be partial. The child who is totally color-blind sees the world in shades of gray; on the other hand, the partially color-blind may have troubles with red, green, gray, brown; and often blue and purple look alike to them while pastels may cause confusion or uncertainty. Another group of color-vision defectives may have trouble with blue and green, see yellow as gray and be unable to recognize violet (Ref. 30, p. 71).

It should be clear to the teacher that children who are totally or

partially color-blind will be frustrated in those situations requiring color discrimination. There is no excuse for failure to screen out those who should be checked more carefully.[5]

Monroe and Roberts recognize the problem of color-vision defects in noting that many reading-readiness books use color, and many instructional materials for young children require some kind of color discrimination. Therefore, the child who is color-ignorant or color-blind is handicapped in participating in pre-reading activities.[11]

Teachers and parents can aid children with color-vision defects and help them solve problems related to this defect. The Association for the Blind and for Sight Conservation Booklet, Your Child in This Colorful World,[10] indicates that much can be done to aid children with color-vision defects and to help them solve related problems.

Students who have color-vision defects may vary in their ability to utilize color effectively.[4,12] Knowledge of students' ability or lack of ability to utilize color can be helpful to educators, textbook authors, guidance counselors, art departments, audiovisual personnel, special education personnel, the school health services, etc., and can be especially important to the individual student and his family.[3,10,13]

Occupational Guidance

Some mild color-vision defects are not a handicap in relation to most occupations, but some severe cases may be affected in their future vocations. Parente and Coady note:

> . . . such fields as police, fire protection, electronics, military service, pilot training, signal corps, and others, have a need of full color vision: thus color-blindness [color-vision defects] would be a definite handicap.(Ref.13, p. 323)

Young people are confronted with the need for an acute sensitivity to color in numerous vocations including medicine, chemistry, biology, aviation, and agriculture. It is essential that employees possess good powers of color discrimination in industries such as art and decoration, advertising, engineering, color photography, photoengraving, and the manufacture of paint, printing ink, ceramics, paper, textiles and clothing. (Ref. 14, p. 201)

Although in general, mild color deficiencies are not believed to hinder careers in many of these fields, the seriously handicapped need guidance.[3]

One color perception test, the Panel D-15 Test, is designed to

separate the genuinely color-blind from the normal and merely color weak . . . . the dichotomy in question is between normal and distinctly abnormal or grossly deficient. The test, of use in industry, military service, and vocational guidance where this distinction is the focal one, is best used in a battery of color-vision tests in the clinic.[15] Since the Panel D-15 Test reveals defects in yellow-and-blue vision it can be used advantageously in cases of ocular pathology, as well as for revealing red and green defects. (Ref. 5, p. 189) Partial loss of vis[illegible] is no obstacle in its use and it can, therefore, be giv[illegible] people with reduced vision.[4] This can be especially important when, in screening children, the unstable characteristics of some "acquired" color-vision defects are considered. Linksz explains that:

> Eye diseases--especially affectations of the optic nerve--can, by the way, also cause an "acquired" (non-heredity) disturbance or red-and-green vision. In contradistinction to the ordinary hereditary color defects these secondary defects are not stable, nor immutable in their manifestations. They follow the tide of the underlying ocular pathology . . . . Inherited disturbances of the yellow-and-blue sense are, in contradistinction, rare, maybe 1 in 30,000. The mode of heredity is not well established. It is certainly not sex-linked. Much more frequent are disturbances of yellow-and-blue vision as a corollary of eye disease, especially diseases of the retina proper.[4]

Mercer points out that:

> Injury or disease of any part of the seeing system--the eye, nerves, or brain--can bring about color blindness (color-vision defects).[10]

Interviews with Students Who Have Difficulty Utilizing Color

Prater interviewed elementary school students and found those with color-vision defects needing special attention in any problem involving color. A junior high student was confused by: (1) the use or color in geometric figures in mathematics, and (2) his inability to determine when steel reached the cherry or strawberry red necessary when heating it for certain processes. A college senior revealed confusion and frustration in several areas where the selection or use of color was important. He found that in a first-grade arithmetic book, the red, brown, pink, and green all looked alike. He said, "I'm glad I didn't have that book in first grade. I would never have learned arithmetic."[3]

The problems encountered by these students may be solved in part if they can be assisted in their adjustment to a world that is extremely color oriented.[3]

Special or Handicapped Students

The adjustment faced by students with color-vision defects can be an important factor in the educational process for some students. The problem of color-vision defects and the inability to utilize color can be compounded when a student has other problems that affect his ability to learn.[3] Color is reported to be pivotal to some learning or remedial situations.[16]

Deviations in Measurements of Color-Vision Defects

Several studies concluded that in the samples employed the percentage of students with color-vision defects was lower than the eight percent often quoted in the literature.[1,2,13] Some studies combined selected portions of the Ishihara Tests and the AO-HRR Test as a measure while the often-quoted frequencies found for red-green color-vision defects of 8 percent in males and 0.68 percent in females are based on the works of VonPlanta in Switzerland and by Wooler in Norway in the 1920's using only the Ishihara Test.[1,2]

Schmidt, in noting that some studies have shown lower percentages of color-vision defects, observes:

> (1) The main reason for small numbers of color deficient is the small number of investigated persons;
>
> (2) Different editions of the Ishihara plates are differently sensitive;
>
> (3) The lighting must be used exactly according to instructions. A 100-watt bulb can cause a color deficient to pass the test;
>
> (4) The examiner is inexperienced, does not follow instructions strictly, gives involuntarily too many cues [which help the subject] to recognize the figures.[17]

The literature indicates that from approximately four to over eight percent of the white male students can be expected to have color-vision defects with the ratio of girls being as low as approximately seven-tenths (0.69) of a percent.[1,2,4]

Color defects are much less common in some races than others. The percentages presented above are the ones usually quoted for the white population. It is this population that has been thus far the most extensively studied.[4]

Summary

The literature reports many examples of problems related to school adjustment and color-vision defects. The importance of effective color-vision screening programs and early diagnosis is stressed. The need for occupational guidance for the older student and the provision of assistance in helping him to understand the areas in which he may encounter some problems is indicated. Additional investigations of materials and methods that appear to be causing problems are encouraged. The authors indicate that more information is needed to better understand the problems related to color-vision defects. The importance of being able to discriminate between colors was repeatedly emphasized. The use of color in many activities related to reading, arithmetic, science, art, and many other school activities and vocational pursuits is noted.

Several studies of possible relationships between color-vision defects and elementary school achievement have provided helpful background material.[3,9,16,18] One of the weaknesses of these studies is that they appear to have pooled or grouped the various types of color-vision defects and made comparisons without testing to determine whether or not the subjects were able to utilize color effectively in spite of their diagnosed color-vision defect.

This study was designed to build on many of the previous studies and to measure the students' ability to use color. This is an important step toward the solution of some of the complex problems related to color-vision defects and toward making "teachers and authorities in different areas . . . aware of the potential problems which exist in the use of color as a controlling factor in learning experiences."[3] It appears vital to develop information to examine the proposition that all color-vision defects are not the same, that color-ignorance exists, and that the problems of students with various color perception difficulties are not all the same.

Knowledge of a student's ability to utilize color as measured by the Panel D-15 Test should be helpful when working with students who have multiple handicaps. Mandola notes:

> The implications of color in relation to learning has not escaped workers in the field of special education and successful teaching techniques where color was pivotal to the learning or remedial situation have been reported.[16]

Instrumentation

The American Optical-HRR Pseudoisochromatic Plate Test (AO-HRR) consists of a series of plates with symbols, not numbers, and permits a graded diagnosis (mild, medium, strong) and a separation of "deutan" (green)

and "protan" (red) defects and also the diagnosis of tritan (yellow-and-blue) defects (in the Ishihara set there are no provisions for diagnosing of yellow-and-blue vision). The AO-HRR plates are very good for quantitative differentiation, (Ref. 23, p. 305) are commonly used by ophthalmologists and optometrists, and have been recommended for school screening programs by the Michigan Department of Public Health. Courtney found that by using the patterns occurring in the AO-HRR Test from cardboard and letting the child choose from these three what they saw on the test, some small children and other subjects who might not respond in the normal manner were able to respond correctly.[35]

The Ishihara Tests for Colour Blindness, Concise Edition, 1970 (Ishihara 14 Plate), a simple screening test with color plates (pseudoisochromatic plates), requires the identification of numbers or pathways (curved lines) made by colored dots on a background of other colored dots.

The person with normal color vision has no difficulty in distinguishing the numbers or curved lines, while the color defective individual cannot identify them. This procedure takes three to five minutes[13] and is described as a test of congenital color vision deficiency.[25] Linksz notes that: "A person who makes not a single mistake reading the Ishihara plates, can confidently be labeled as color-normal." (Ref.4, p. 188) The Ishihara Test is often used by medical doctors in diagnosing, and earlier editions were used in the early studies often quoted in the literature by von Planta in Switzerland and by Wooler in Norway in the 1920's which found frequencies of red-green color-vision defects of 8 percent in males and 0.68 percent in females.1

Crone's studies indicate that Plate No. 1 of the Ishihara Test was read correctly by all the defectives and all the normals and that the Ishihara plates have proven excellent for differentiation between normal and abnormal. (Ref. 23, p. 305) The Ishihara Test differs from the AO-HRR in that editions of the Ishihara have plates that "both normal and color-blind read the figures alike," (Ref. 22, p. 3) and a second plate with a winding line that... "tracing the winding line is easy to do so for both normal and color-blind." (Ref. 22, p. 7)

Macbeth Easel Lamp (New London Easel Lamp) Any color test using reflected light is dependent upon the spectral composition of the illuminant used. (Ref. 26, p. 9) The Macbeth Easel Lamp, designed for color-vision testing by the Macbeth Corporation is recommended for use with the AO-HRR Test and the Panel D-15 Test.[8,12] Care should be taken to prevent direct light from "tungsten or fluorescent lamps or outside windows" from reaching the test plates. (Ref. 26, p.6)

Linksz points out that it is mandatory that the AO-HRR Test be administered under illumination of CIE* source C, or a close approximation,

* C.I.E. (Commission International de l'Eclairage) also can be written I.C.I., the usual form for International Commission on Illumination.

and that the illumination intensity must be between 10 and 60 foot-candles. "The Macbeth Instrument Company manufactures an easel lamp to furnish the type of illumination required. I use it in connection with all pigment-color tests."(Ref. 8, p. 203)

Dvorine Nomenclature Test For the purposes of this study only the Nomenclature Subtest of the Dvorine Pseudo-Isochromatic Plates, Second Edition was employed. This color-naming test consists of a revolving nomenclature chart comprised of a 1-inch circular exposure-window which exposes in turn each of eight saturated colors and eight tints. This test helps to identify those subjects who are color ignorant.[27] The test contains several features which are designed to thwart malingering subjects. The Macbeth Easel Lamp provides standardized illumination during testing with the Dvorine Nomenclature Test.

The Panel D-15 Test was used not as a screening test, but as an instrument to measure the color-vision deficient student's ability to utilize color. Linksz stated at an American Academy of Ophthalmologists and Otolaryngologists, in October, 1970, that "any subject who passes this test will have no difficulty in performing almost any task in which color-vision is a factor, even if more stringent tests (with the anomaloscope or the Ishihara Plates) might have labeled ' m as color-vision defective (The Panel D-15 is not a screening test!)"[28] He noted also that anybody over age five should not have trouble taking the Panel D-15 Test.[29] "The chroma of the Farnsworth Panel D-15 color chips is so chosen that those with only a mild defect should pass the test. The test serves practical rather than theoretical classification." (Ref. 8, p.90) The Macbeth Easel Lamp was used for illumination during the testing with the Panel D-15 Test. (Ref. 8, p. 90)

A more detailed description of the Instrumentation and materials involved in testing is presented in Appendix II.

Scope of the Project

This project was designed to test a large segment of school aged children to determine various color-vision related information. Subjects from kindergarten, second, and seventh grade levels were screened to determine the prevalence of color-vision defects as measured by a variety of instruments, to ascertain the ability of color-vision defective and color-vision normal subjects to utilize color, and to ascertain the degree of color-ignorance manifested by color-vision normal subjects.

Subjects of both sexes were employed and the various racial groups present in the population which was sampled were represented in the study in approximately the same proportions as found in the school system.

Testing of the subjects for color-vision defects was conducted by trained examiners under controlled conditions. This served to effectively eliminate many of the faults existing in previous investigations of color-vision defects and to provide as valid data as possible.

The data resulting from the investigation were extensively analyzed and cross-referenced to provide in-depth information concerning the performance of the subjects.

Definitions

For the purposes of this study certain technical terms were defined as follows:

Selected Subjects from Outside the Sample: Various color-vision defective people included in preliminary screenings.

Color-Blindness: A commonly and inaccurately used term (inaccurate when used to describe the inablity to perceive one or more colors) referring to diminished ability to perceive color. The term color-blindness is accurate only when a person is totally color-blind and appears to perceive colors only as black, white, and shades or tints of gray.

Color Deficient: Those individuals whose ability to perceive color deviates from the normal.

Color-Vision Defect: Deviation from normal performance on any of the color-vision screening instruments (AO-HRR and Ishihara Tests).

Color-Vision Deficient Group: Those subjects found to have some degree of color-vision deficiency on both of the Ishihara Tests and the AO-HRR Test.

Color-Vision Normal Control Group: Those Subjects found to have not failed on any administration of the color-vision screening tests (Ishihara and AO-HRR).

nm (Nonometer): 10^{-9} meter. Positions in the spectrum are identified by wave length numbers expressed in "nm."

Saturation: That attribute of color which may be distinguished along a continuum, such as red . . . pink . . . white. The less saturated a color, the closer it is to white.

Desaturation: Reduction of saturation (decrease in the hue of the color concerned).

Acquired Defects: Those defects which are not congenital and tend to be unstable.

Protanope (Protanopia): Red blind defect. The area around 490 nm is colorless.

Protanomalous (Protanomalia): Red weak defect. The area around 490 nm is very desaturated (hard to distinguish).

Deuteranope (Deuteranopia): Green blind defect. The area around 500 nm is colorless.

Deuteranomalous (Deuteranomalia): Green weak defect. Confusion of red and green areas. The area around 500 nm is very desaturated.

Tritanope (Tritanopia): Complete failure in the appreciation of blue and yellow.

Tritanomalous (Tritanomalia): Partial failure in the appreciation of blue and yellow.

"Color-Ignorant": Subjects with normal color-vision as measured by the AO-HRR and Ishihara Tests who have not learned to correctly name colors on the Dvorine Nomenclature Test with the scoring for the Kindergarteners as follows: three or more errors on the "dark tints" (shades) and/or five or more errors on the "light tints." The second and seventh graders were scored as follows: two or more errors on the "dark tints" (shades) and/or four or more errors on the "light tints" were classified as "color-ignorant."

"Invalid": On the Panel D-15 classification of Pass/Fail/Invalid, "invalid" was used to indicate that the subject's results were irratic or unusual and not easily scored by the published standards. On the Panel D-15 classification of Type, "Invalid" indicates that the type varied from the usual pattern and was not described in the published standards.

Limitations of the Study

One of the limiting factors in the study was that it was not designed to investigate the performance of subjects on color-vision related tasks in the school setting or in any other setting outside of the controlled one. No attempt was made to investigate the compensatory mechanisms operative in the utilization of color by color-vision defective subjects.

A second limitation of the study was the absence of standardized and accepted criteria for pass/fail on the Dvorine Nomenclature Test. Lack of pre-established criteria necessitated a rather arbitrary criterion to be established to determine color-ignorance among the color-vision normal subjects.

A third limitation which was present in the study centered around the measure of socio-economic status (SES) which was available for the subjects. The measure (Appendix III) was a very gross one based on generalizations made about the school population as a whole rather than based upon individualized criteria. It is rather doubtful whether the SES data presented in the study is truly representative of the status of the individual subjects and thus its relationship to the findings must be questioned.

Another limitation is associated with the fact that some of the subjects in the color-vision normal and color-vision defective groups at the kindergarten and second grade level scored invalid test results on the Panel D-15 Test. It would appear that this was due primarily to the fact that these subjects did not possess the skill required to perform such a test, namely color matching.

Hypotheses

In investigation of the ability of subjects with color-vision defects and color-vision normal subjects to utilize color the following hypotheses were presented:

1) There will be no difference in the proportion of color-vision defects present at the second and seventh grade levels.

2) Some of the subjects in the color-vision defective group will be able to utilize color as measured by the Panel D-15 Test.

3) All of the subjects in the color-vision normal group will be able to utilize color as measured by the Panel D-15 Test.

4) Some of the color-vision normal subjects will manifest color-ignorance as measured by the Dvorine Nomenclature Test.

CHAPTER II---PROCEDURES

Sample

The population from which the sample was drawn consisted of kindergarten, second, and seventh grade students enrolled in the Grand Rapids, Michigan, Public Schools. The total school enrollment for the Grand Rapids system for the 1971-72 school year was 34,468 pupils. The kindergarten, second, and seventh grade enrollment was 3,037, 2,525, and 2,576 pupils respectively. A total of 2,476 subjects were employed as the initial sample. This sample was selected on the basis of criteria established by the Grand Rapids Public Schools (GRPS) and was thus not completely random in nature. The decision as to which schools would be included in the sample was made based upon the following criteria. A major consideration was the presence of a school nurse in the schools selected. This was necessitated by the fact that the school nurses were the examiners for the project. In certain instances, schools not having a school nurse were included at the request of the GRPS. These schools were included to help balance the socio-economic representation in the sample. This, however, resulted in the total number of subjects studied exceeding the number originally proposed. The GRPS also requested that some additional students in kindergarten and second grade levels be included in the study. This not only increased the final number of subjects but also served to increase the number of black students in the study. Some adjustments were also made in the sample in an attempt to balance racial distributions as closely as possible. It was, however, felt important that a large percentage of black subjects be included in the sample since there has been minimal data reported on the prevalence of color-vision defects in this segment of the population.

The initial sample of 2476 subjects was comprised of 1235 males and 1239 females. In two instances the sex of the subjects was not specified and could not definitely be determined from the names of the students. A description of the sample by sex and grade placement is presented in Table 1.

Table 1
Sample Reported
by Grade Level and Subject Sex

Level	Male	Female	Not Specified	Total
Kindergarten	221	240	0	461
Second Grade	491	481	1	973
Seventh Grade	523	518	1	1042
Totals:	1235	1239	2	2476

The racial composition of the sample was also identified for each grade level. A total of 1674 Caucasian subjects, 764 black students, 23 of other racial origin and 15 subjects whose racial origin was not specified or was not known. A summary of the racial composition of the sample by grade level is presented in Table 2.

Table 2
Sample Reported By
Grade Level and Racial Origin

Level	Caucasian	Black	Other	Not Specified	Total
Kindergarten	320	131	9	1	461
Second Grade	538	422	6	7	973
Seventh Grade	815	211	8	8	1042
Totals:	1673	764	23	16	2476

The sample was also analyzed by race and sex (Table 3) and by race, sex, and grade level (Table 4).

Table 3
Sample Reported By
Racial Origin and Sex

Race	Male	Female	Not Specified	Total
Caucasian	836	837	0	1673
Black	386	378	0	764
Other	5	18	0	23
Not Specified	8	6	2	16
Totals:	1235	1239	2	2476

Table 4
Sample Reported By
Race, Sex and Grade Level

Race and Sex	Kindergarten	Second	Seventh	Total
Caucasian				
Male	154	271	411	836
Female	166	267	404	837
Total	320	538	815	1673
Black				
Male	64	217	105	386
Female	67	205	106	378
Total	131	422	211	764
Other				
Male	2	0	3	5
Female	7	6	5	18
Total	9	6	8	23
Not Specified				
Male	1	3	4	8
Female	0	3	3	6
Total	1	6	7	14
Totals:	461	972	1041	2474*

*Two subjects did not have their sex specified.

In addition to the above description of the sample the socio-economic level of the subjects was reported. The information was provided by the GRPS. A summary of the SES of the subjects as derived for the GRPS is included in Appendix IV. The results indicated the Grand Rapids Schools to be comparable to other middle size school districts in the State of Michigan. The SES was divided into five equal percentile rankings with the ranking of five being the highest twenty percent of the socio-economic ranking and a score of one being the lowest twenty percent. A description of the SES of the subjects in the color-vision normal and color-vision defective groups is presented in Table 5. The SES of the two groups are the same because the control group was matched with the color-vision defective group by school.

Table 5
Socio-Economic Status of Color-Vision Normal
and Color-Vision Defective Subjects by Grade Level

SES Percentile Rank	Color-Vision Normal and Color-Vision Defective			
	Kindergarten	Second	Seventh	Total
81-99	2	5	Ø	7
61-80	Ø	Ø	8	8
41-60	1	1	Ø	2
21-40	2	5	8	15
1-20	0	4	Ø	4
Not Specified*	Ø	2	Ø	2
Totals:	5	17	16	38

*No SES data available for two schools Ø No schools in this category

Following administration of the battery of tests, the subjects comprising the "color-vision defective" group were identified; and the random selection of the "color-vision normal" subjects for the control group was completed. The control group consisted of color-vision normal subjects randomly selected from those subjects who had passed the first administration of the AO-HRR Test. At each school the subjects who had passed the test were listed in numerical order. The examiner, using a table of random numbers, selected subjects at the school and at each grade level. These subjects were then tested with the second administration of the AO-HRR Test and the Ishihara Tests and only those subjects that passed all the tests were placed in the final control group. Color-vision normal and color-vision defective subjects were matched as closely as possible as to grade level and school placement. In two instances the grade level of the subjects was the same but the school placement differed.

The chronological ages of the color-vision normal and color-vision defective subjects by grade level are presented in Table 6. The ages are given in months, computed as of March, 1972.

Table 6
Means and Standard Deviations of
Chronological Ages for the Color-Vision
Normal and Color-Vision Defective Groups (In Months)

Level	Color-Vision Normal N	$\bar{X}$	Sd	Color-Vision Defective N	$\bar{X}$	Sd
Kindergarten	5	69.40	3.91	5	72.00	2.35
Second Grade	17	92.78	4.69	17	95.07	6.90
Seventh Grade	15	158.70	6.11	14	157.40	8.20
Total:	37			36*		

*Data missing for two subjects at seventh grade level.

General Procedures

This study was undertaken for several reasons. It was designed to identify the percentage of the sample at each grade level that manifested color-vision defects as measured by the AO-HRR screening tests and the Ishihara Tests. A second reason was to assess the ability of color-vision defective and color-vision normal subjects to utilize color as measured by the Panel D-15 Test. A third reason was to determine the "color-ignorance" of color-vision normal subjects and to report the results by colors to indicate those that cause problems for color-vision normal and color-vision defective subjects.

The specific types and degrees of color-vision defects present in the sample were classified as measured by the AO-HRR Test. To verify these findings and to control for selected variables, the Ishihara and the AO-HRR color-vision screening tests were administered to selected color-vision normal subjects just prior to their being placed in the "color-vision normal" control group and to the color-vision defectives just prior to their being placed in the "color-vision defective" group.

The color-vision defective group's ability to utilize color, despite their color-vision defect, was measured by the Panel D-15 Test. This information was compiled for each grade level to determine variations that existed at various levels of development and maturation. The color-vision normal control group's ability to utilize color as measured by the Panel D-15 Test was also obtained for each grade level.

This study employed the Dvorine Nomenclature Test in an attempt to identify color-vision normal subjects who were "color-ignorant" and to determine the types of colors missed by color-normal subjects. The color-vision defective group was also tested with the Dvorine Nomenclature Test to determine to what extent they could identify colors at each grade level.

In some kindergarten situations certain colors present on the Dvorine Nomenclature Test are not stressed. Therefore, the scoring of this test had to be adjusted to allow for this variation in the experiences of the younger subjects.

Comparisons were made between the performance of color-vision defectives on the AO-HRR Classification, the Dvorine Nomenclature Test, the Panel D-15 Test and the Ishihara Test to determine possible relationships.

Preliminary Activities

Screening of Examiners

Examiners selected for administering the color-vision test in the study were nurses from the GRPS. The school nurses were screened for color-vision defects prior to being assigned to the project. The color-vision tests were administered to the nurses by the principal investigator using the AO-HRR Test. No nurses were found to be color-vision defective. One individual was eliminated, however, due to visual accommodation problems.

Training of Examiners

Validity of the study was highly dependent upon reliable color-vision screening techniques being employed by the examiners. To insure a high degree of reliability, an intensive training program for the examiners was undertaken. The objectives of this program are presented in Apendix V. In order to facilitate the training, a series of videotaped presentations were professionally prepared. These illustrated the testing procedures to be employed, detailed problems which might be encountered in the color-vision screening, familiarized the examiners with variables which must be controlled in color-vision screening, and detailed the materials and supplies required to test the subjects employed in the study.

Following the group instruction of the examiners, individual training was presented. The intensity and length of individual training sessions was dependent upon the amount of time required for each examiner to reach criterion performance. An example of the criterion performance which was specified is detailed in Appendix VI. Examiners were provided materials and programmed testing situations through which they were able to gain experience in the examination and scoring procedure. A total of fourteen examiners met the criteria and were assigned to do the color-vision testing for the project.

Throughout the course of the project, individual examiners received additional training just prior to the initiation of each phase of the screening procedure. The individual training was highly dependent upon the phase of the screening which was being engaged in by the examiners. Each phase required specific individual instruction prior to its initiation and the examiners progressed at their own rate.

Phase I: Initial Screening--Total Sample

The initial screening program was employed for control of malingering and/or totally color-blind subjects. Kindergarten and second grade subjects were given a pretest to aid in the development of meaningful communication concerning the test symbols (See Appendix VII). The four demonstration plates of the AO-HRR Test were administered to all subjects. Subjects with incorrect responses or no response to these plates were temporarily classified as "Malingering or totally color-blind." These subjects were further screened with the Alternate Schedule for Malingering, Aberrant or Totally Color Blind Subjects. (See Appendix VIII)

Subjects classified tentatively as malingering, aberrant or totally color-blind because of their lack of response to the AO-HRR demonstration plates were screened with the Ishihara Plates (38 Plate Edition) numbers one and thirty-eight. These consist of plates that the totally color-blind can see.[22] Subjects responding correctly to these plates were tested with the AO-HRR Test as outlined in the screening schedule below.

Malingering or otherwise aberrant subjects were next given a special adaptation of the AO-HRR Demonstration Plates and instructed to choose the cards depicting the shape or shapes seen. Subjects able to utilize the cards to indicate correct reponse to the AO-HRR Demonstration Plates were then tested with the remainder of the AO-HRR Test utilizing the cards.

Subjects unable to see or not able to communicate the responses to plates one and thirty-eight of the Ishihara or the special adaptation of the AO-HRR Plates were kept separate to control for malingering or aberrant subjects and their teachers contacted to determine the nature of the problem. Some of these subjects were retested later when deemed advisable.

Those subjects not found malingering or otherwise aberrant were next tested with the screening series of the AO-HRR (Plates 1-6). Subjects making no errors on these plates were classified as "color-vision normal." Those subjects making errors on the AO-HRR Plates 1-6 were further screened with the appropriate Diagnostic Series of the AO-HRR Test. Subjects making no errors on the Diagnostic Series were then retested on Plates 1-6 with the test book placed on the Macbeth Easel so that the location of the symbols was changed for the retesting. Subjects making no errors at this time were classified as

color-vision normal. These subjects were, however, excluded from possible selection for the control group. A graphic illustration of this phase is presented in Appendix IX.

Phase II: Second Screening
Selection of Color-Vision Defective Group and Control Group

A randomly selected group of color-vision normal subjects were retested with the total AO-HRR and Ishihara Tests in order to insure that the control group did not contain any color-vision defectives or subjects with unstable characteristics of some "acquired" color-vision defects. Subjects who failed on any of these tests were not placed in the control group. Subjects were matched with the color-vision defective group by grade and school.

Color-vision defective subjects were also tested with the AO-HRR and Ishihara Tests to insure that none manifested the unstable characteristics of "acquired" color-vision defects, and to verify the type of color-vision defect present. Those found to be consistently color-vision defective made up the "color-vision defective" group. To control for subjects failing the Ishihara Test because of possible illiteracy, a version of the Ishihara Test for Unlettered Persons was also administered to both groups. The final groups were approximately equal in number with thirty-seven in the control group and thirty-six in the experimental group. Appendix X presents this phase graphically.

Phase III: Panel D-15 Test
Control and Color-Vision Defective Groups

Subjects in the color-vision defective group and the control group, or color-vision normal subjects, were next given the Farnsworth Dichotomous Test for Color Blindness (Panel D-15). This test was administered to determine the ability of the subjects to utilize color. Phase III is represented graphically in Appendix XI.

Phase IV: Dvorine Nomenclature Test
Control Group, Color-Vision Defective Group and Other Selected Subjects

To test for color-ignorance, Dvorine's Nomenclature Test was administered to all kindergarten subjects who passed the AO-HRR Test and to approximately 250 selected second and seventh grade subjects who had passed the first or second administration of the AO-HRR Test.

Those second and seventh grade subjects who made two or more errors on the "dark tints" and/or who made five or more errors on the "light tints" were classified as color-ignorant. The color-vision defective group was also tested with Dvorine's Nomenclature Test. No pre-

existent criteria for classification of subjects as color-ignorant were employed. The classifications were made on a rather arbitrary basis as a result of interviews with kindergarten and early elementary teachers.

Both color-vision normal and color-vision defective subjects' scores were recorded indicating the number of errors and the specific responses given to each color as well as indicating the specific colors missed. Appendix XII illustrates the Fourth Phase graphically.

A description of the instruments employed in Phases I - IV is presented in Appendix II.

Methods of Data Analysis

With the exception of information related to the chronological ages of the subjects, the data resulting from this investigation were nominal and ordinal in nature. The data consisted of frequencies of subjects who, as a result of test performance, fell into various categories with reference to color-vision. This type of data is not amenable to parametric statistical treatment and in most instances was best represented by descriptive statistics.

In testing the hypotheses nonparametric statistics were exclusively employed. These statistical techniques were found to be the ones most appropriate for the testing of the hypotheses due to the nature of the data. Both Chi-Square One-Sample Tests and Kolmogorov-Smirnov One-Sample Tests were employed. The Chi-Square Test was utilized when the expected frequencies were large enough to warrant its use. In those instances where the expected frequencies were prohibitively small, the Kolmogorov-Smirnov Test was employed.

Through the use of computerized storage and retrieval methodology, a multitude of cross-comparisons were made. The voluminous amount of data necessitated the most parsimonious analysis and presentation of the data to permit meaningful conclusions to be drawn.

CHAPTER III---RESULTS

Sample

From the initial sample of 2476 subjects, a total of thirty-eight were found to be color-vision defective on all tests and comprised the color-vision defective group. The control or color-vision normal group consisted of thirty-seven subjects. Data associated with student performance at different phases of the screening were also collected.

Of the 2476 subjects who received the first administration of the AO-HRR, a total of 2056 were found to be color-vision normal. From those who passed the first administration of the AO-HRR, subjects were randomly selected for retesting with the AO-HRR Test and the Ishihara Tests. Only subjects who passed all administrations of the tests were eligible for placement in the "color-vision normal" control group. One subject was found to have some problems with the Ishihara 14-Plate Test and was therefore not included among the subjects eligible for the color-vision normal control group.

Two hundred seventy-five subjects were classified as color-vision defective as the result of the first administration of the AO-HRR Test but were not defective on the second administration. An additional fifty subjects were identified as color-vision defective on the first and second administrations of the AO-HRR Test and passed at least one of the tests presented during Phase II.

Those subjects found to be color-vision defective on both administrations of the AO-HRR and also defective on both Ishihara Tests were placed in the color-vision defective group.

A total of five subjects were unable to be tested due to uncooperativeness, malingering behavior, or behavior which was in some way abberant. An additional 42 subjects who failed the first administration of the AO-HRR Test were not retested because they were absent, had moved, were expelled, etc. Data for ten of the subjects were incomplete. Table 7 presents a summary of the grouping of the total sample by test performance.

Subjects in the color-vision normal control group and the color-vision defective group and selected other subjects were administered the Dvorine Nomenclature Test to ascertain color-ignorance. A total of 767 subjects were administered the Dvorine Nomenclature Test to ascertain the colors that appeared to be causing problems among color-vision normal and color-vision defective subjects at various grade levels.

Table 7
Sample Reported by Group Placement

Group	Number	Percentage
1	2018	81.50
2	37	1.49
3	1	.04
4	275	11.11
5	50	2.02
6	38	1.53
7	5	.20
8	42	1.70
9	10	.40
Totals:	2476	99.99

Group 1--Color-vision normal on first AO-HRR but not selected for the control group.
Group 2--Color-vision normal control group.
Group 3--Color-vision normal on first AO-HRR. Randomly selected for Phase II testing and encountered problems on Ishihara 14.
Group 4--Color-vision defective on first administration of AO-HRR; not defective on second administration of AO-HRR.
Group 5--Color-vision defective on first and second administrations of AO-HRR and passed one or two of Ishihara Tests in Phase II.
Group 6--Color-vision defective group. Failed first and second administrations of AO-HRR and also failed Ishihara Tests.
Group 7--Subjects who were unable to be tested.
Group 8--Subjects who moved, were expelled, etc.
Group 9--Subjects on whom data were incomplete.

The color-vision normal control group and those subjects in the color-vision defective group were also administered the Farnsworth Panel D-15 Test to ascertain their ability to utilize color.

Hypotheses

The following research hypotheses were presented for this study:

1) There will be no difference in the proportion of color-vision defects present at the second and seventh grade levels.

2) Some of the subjects in the color-vision defective group will be able to utilize color as measured by the Panel D-15 Test.

3) All of the subjects in the color-vision normal group will be able to utilize color as measured by the Panel D-15 Test.

4) Some of the color-vision normal subjects will manifest color-ignorance as measured by the Dvorine Nomenclature Test.

These research hypotheses were translated into the null form to permit statistical testing. The following represent the null hypotheses and the related results.

Hypothesis I. The proportion of color-vision defects present at the second and seventh grade levels will not be equal.

In testing this hypothesis, the number of color-vision defects that were identified by each of three criteria was utilized. The criteria employed to determine the existence of color-vision defects were:

1) Failed the first administration of the AO-HRR Test and passed the second administration (tentatively labeled as color-vision defective).

2) Failed the first and second administration of the AO-HRR Test but passed at least one of the tests in the second testing session.

3) Failed the AO-HRR and Ishihara Tests at every administration.

The total number of subjects identified by each of the criteria was first ascertained. This number was employed to determine the proportion of color-vision defects as assessed by each criterion which was found in the total sample. This proportion was employed to determine the number of subjects which would be expected at each level if the research hypothesis was correct for that criterion. The kindergarten subjects were also included in the analysis even though the proportion of color-vision defects was not hypothesized for this level. The expected and observed frequencies of subjects at each grade level for each criterion were then analyzed by means of the One-Sample Chi-Square Test (Siegel, 1956). Table 8 presents a summary of this test for each of the three criteria at each grade level.

Table 8
Chi-Square Summary for
Subject Performance on the Criteria
Measures at Each Grade Level

Criterion	Kindergarten		Second		Seventh		χ^2	df
	O	E	O	E	O	E		
1	70	51.17	150	108.00	55	115.66	58.94*	2
2	29	9.54	19	20.14	2	21.57	60.10*	2
3	5	7.05	17	14.89	16	15.94	.92	2

O--Observed Frequencies
E--Expected Frequencies

*$p < .001$

When criterion one was employed, a significant difference was found between the grade levels. Inspection of the data indicates for this criterion there were more color-vision defective subjects than expected at the kindergarten and second grade levels and fewer than expected at the seventh grade level.

Use of criterion two also resulted in a significant difference between levels. There were more subjects with color-vision defects found at the kindergarten level and fewer found at the seventh grade level than would be expected if the proportion had been the same for all grade levels. There was no appreciable difference between the observed and expected frequencies at the second grade level for this criterion.

When the third, and most stringent, criterion was employed, it was found that no significant differences existed between the proportion of subjects found at each of the three grade levels.

As a result of these data, the hypothesis was retained for the first and second criteria and rejected when the third criterion was employed. This indicates that the research hypothesis was not found to be correct when the first two criteria were employed but was correct when the last was utilized.

Hypothesis II. The number of subjects in the color-vision defective group who demonstrate the ability to utilize color will not significantly differ from zero.

In testing this hypothesis only the subjects who failed the AO-HRR and Ishihara Tests at every administration were included. A total of thirty-eight subjects were found to be classified, for the purpose of this analysis, as color-vision defective. Two of these subjects were identified as having color-vision defects but were not included in all analyses as test results were invalid. In hypothesizing that there would be no subjects who could pass the Panel D-15 Test from the color-vision defective group, the resulting expected frequencies for subjects who would fall in the "pass" category was zero. To be able to employ the One-Sample Chi-Square Test, no expected frequency can be zero. This necessitated the use of the Kolmogorov-Smirnov One-Sample Test (Siegel, 1956). This test, which is a goodness-of-fit nonparametric test, is employed to determine if the observed distribution of frequencies in the sample is the same as the distribution which was theorized. In this instance it was theorized that there would be no subjects passing the Panel D-15 Test.

Analysis was conducted for the group as a whole and for each separate grade level. The following results were obtained from this analysis.

Of the total group of color-vision defective subjects (38) it was found that ten were able to pass the Panel D-15 Test and twenty-six failed. Employing the Klomogorov-Smirnov Test it was found that the Maximum Deviation (D) was equal to .278. In order to reject the null hypothesis a D of .226 is required. Since the observed D was greater than the D required for rejection, the null hypothesis for the total group of color-vision defective subjects was rejected (Table 9).

At the kindergarten level only four subjects were found to be color-vision defective. It was theorized that all four would fail the Panel D-15 Test. In actuality two subjects failed and two passed. The resulting D was .500. To reject the null hypothesis at the .05 level a D of .624 is required for an N = 4. Since the observed D was less than that required for rejection, the null hypothesis for this level was retained. The observed distribution did not significantly differ from the theorized distribution.

A total of sixteen subjects were found to be color-vision defective at the second grade level. For an N = 16, a D of .328 is required for rejection of the null hypothesis. A total of three subjects were found to have passed the Panel D-15 Test at this level while thirteen failed. The resulting D was .187, which was not sufficient to reject the null hypothesis. For the second grade level the null hypothesis was retained.

At the seventh grade level there were also sixteen subjects who were identified as being color-vision defective. Of these sixteen, five passed the Panel D-15 Test and eleven failed. This resulted in a D of .312 which is smaller than the D of .328 required to reject the null hypothesis at the .05 level for an N = 16. This necessitated retention of the null hypothesis for the seventh grade level.

Table 9
Kolmogorov-Smirnov Summary
for Color-Vision Defective Performance
on the Panel D-15 Test

Level	Pass	Fail	N	D
Kindergarten	2	2	4	.500
Second Grade	3	13	16	.187
Seventh Grade	5	11	16	.312
Total Sample	10	26	36**	.278*

*$p < .001$
** Two subjects not included as results were invalid on the Panel D-15 Test.

Hypothesis III. The number of subjects in the color-vision normal control group who demonstrate a lack of ability to utilize color will not significantly differ from zero.

As was the case in testing the second hypothesis, the small expected frequencies resulting from the theorized distribution necessitated the use of the Kolmogorov-Smirnov One-Sample Test.

For the color-vision normal control group it was theorized that none would fail the Panel D-15 Test. The observed distribution of performance was then compared to the theorized distribution by the use of the Kolmogorov-Smirnov Test. The hypothesis was tested using the total sample and the subjects at each grade level considered separately.

A total of thirty-three subjects who were in the color-vision normal control group took the Panel D-15 Test and scored usable scores. Of these thirty-one passed the test and two failed. The resulting D was .061. For N = 33, a D of .240 is required to reject the null hypothesis at the .05 level. The hypothesis was thus retained for the total sample of color-vision normal subjects.

At the kindergarten level all four of the color-vision normal subjects passed the Panel D-15 Test with a resulting D = 0. The hypothesis for this grade level was retained.

Two of the fifteen subjects at the second grade level failed the Panel D-15 Test. This resulted in a D = .133 which is a value less than the D = .338 required for rejection of the null hypothesis at the .05 level for an N = 15.

At the seventh grade level, all fourteen subjects passed the Panel D-15 Test. The resulting observed distribution of scores was thus identical to the theorized distribution resulting in a D = 0 so the hypothesis was retained. Table 10 presents a summary of the Kolmogorov-Smirnov scores for the color-vision normal control group.

Table 10
Kolmogorov-Smirnov Summary
Color-Vision Normal Control Group Performance
on the Panel D-15 Test

Level	Pass	Fail	N	D
Kindergarten	4	0	4	0
Second Grade	13	2	15	.133
Seventh Grade	14	0	14	0
Total Sample	31	2	33	.061

Hypothesis IV. The number of color-vision Normal subjects who fail the Dvorine Nomenclature Test will equal zero.

As with the second and third hypotheses, the Kolmogorov-Smirnov One-Sample Test was employed to test the observed distribution of scores against the theorized distribution. The hypothesis was tested for the total sample and also for each grade level separately.

It was found that of the thirty-seven subjects in the control group who took the Dvorine Nomenclature Test none failed. The theoretical and observed distributions were thus in agreement, so the hypothesis was retained in all instances.

Other Findings

In addition to the data relative to the testing of the hypotheses, other data of importance and interest were derived. These other findings are, in some instances, provided as supportative or elaborative data and in other instances presented as additional data relevant to color-vision.

Subjects Classified As Color-Vision Defective as a Result of Phase I

The procedures included in Phase I of the testing program served to provide a general measure of subjects who either were malingering or who had color-vision defects. As a result of the preliminary screening conducted during this phase, the following results were obtained (Table 11).

Table 11

Percentage of Subjects Classified as Color-Vision Defective at the End of Phase I Testing by Racial Origin and Sex

Racial Group	N	Total N	Percentage
Caucasian			
Males	131	836	15.670
Females	129	837	15.412
Total	260	1673	15.541
Black			
Males	49	386	12.694
Females	49	378	12.963
Total	98	764	12.827
Other			
Males	0	5	0.000
Females	3	18	16.667
Total	3	23	13.043
Unknown			
Males	0	8	0.000
Females	1	6	16.667
Unknown	1	1	100.000
Total	2	15	13.333
Total Sample	363	2475*	14.667

*Data for one subject was incomplete, thus reducing the total sample size for this analysis by one.

A breakdown of the 363 subjects temporarily classified as color-vision defective at the end of Phase I by Group Placement and Grade Level reveals some of the differences that existed at the three different grade levels and is presented in Table 12.

Table 12

Percentage of Failures at Each Grade Level on the First Administration of the AO-HRR

Grade Level	Group*	N	Percentage
Kindergarten (461)	4	70	
	5	29	
	6	5	
		104	22.5
Second (973)	4	150	
	5	19	
	6	17	
		186	19.1
Seventh (1042)	4	55	
	5	2	
	6	16	
		73	7.0

*See Table 7 for description of groups

The percentage of failures on the first administration of the AO-HRR was 22.5 percent at the kindergarten level, 19.1 percent at the second grade level and 7.0 percent at the seventh grade level (Table 12).

Table 13

Number of Failures on the First and Second Administration of the AO-HRR Test Who Only Missed Plate No. 3--By Grade Level

Level and Group*	First Adm. AO-HRR	Second Adm. AO-HRR
Kindergarten		
Group 4 (70)	64	0
Group 5 (29)	26	19
Group 6 (5)	0	1
Second Grade		
Group 4 (150)	126	0
Group 5 (19)	15	17
Group 6 (17)	0	2
Seventh Grade		
Group 4 (55)	38	0
Group 5 (2)	0	1
Group 6 (16)	0	0

*See Table 7 for description of groups

The AO-HRR Plates were found to yield a high frequency of failure on the Screening Series, especially Plate 3. There were 325 students in Group 4 and Group 5. Of these 269 or 82.7 percent missed only Plate 3 on the first administration of the AO-HRR (see Table 13).

The criteria for inclusion in Group 5 was failure on both Administrations of the AO-HRR combined with passing a subsequent administration of at least one of the Ishihara tests. There were twelve Caucasian males in Group 5 (seven in Kindergarten, five in second and none in seventh). Thirty Caucasian males who had failed both administrations of the AO-HRR and both of the Ishihara Tests were in Group 6. This resulted in a total of forty-three, or five percent, of the Caucasian males classified as color-vision defective at the conclusion of the Second Administration of the AO-HRR Test.

Subjects Classified as Color-Vision Defective at the End of Phase II

As a result of the second phase of the screening procedure, only those subjects who consistently demonstrated color-vision defects were placed in the color-vision defective group. This was the most stringent criterion employed. These subjects failed on all administrations of the AO-HRR and the Ishihara Tests. The results of the classification by racial origin is presented in Table 14.

Table 14
Percentage of Subjects Included in the Color-Vision Defective Group at the End of Phase II Testing by Racial Origin and Sex

Racial Group	N	Total N	Percentage
Caucasian			
Males	30	836	3.589
Females	2	837	.239
Total	32	1673	1.912
Black			
Males	6	386	1.554
Females	0	378	0.000
Total	6	764	.785
Other			
Males	0	5	0.000
Females	0	18	0.000
Total	0	23	0.000
Unknown			
Males	0	8	0.000
Females	0	6	0.000
Unknown	0	1	0.000
Total	0	15	0.000
Total Sample	38	2475*	1.455

*Data for one subject was incomplete thus reducing the total sample size for this analysis by one.

To ascertain if the differences in the proportion of Caucasian and Black males who manifested color-vision defects on all tests were significant, a test for the Significance Between Proportions (Ferguson, 1966) was employed. The results, Table 15, indicate that a significant difference exists between the two groups with the proportion of color-vision defective Caucasian males being significantly higher than the proportion of color-vision defective Black males.

Table 15
Differences in Proportion of Color-Vision Defective Caucasian and Black Males at the end of Phase II

Racial Group	N	Total N	P	z
Caucasian	30	836	.035885	1.96*
Black	6	386	.015544	
Total	36	1222		

*$p < .05$

Color-Vision Normal Group and
Color-Vision Defective Group
Performance on the Panel D-15 Test

Data were analyzed for the color-vision normal control group and the color-vision defective group to ascertain whether subjects at differing grade levels differed significantly in their performance on the Panel D-15 Test. The One Sample Chi-Square Test was employed to test this hypothesis. The expected cell frequencies were determined by ascertaining the proportion of individuals in the particular sample group which passed the test and using this to determine the number that would be expected in each cell entry if there was no difference in the distributions between the grade levels. These data are presented in Tables 16 and 17.

Table 16
Color-Vision Normal Control Group Performance
on the Panel D-15 Test Analyzed by Grade Level

	Kindergarten		Second		Seventh		N	χ^2	df
	O	E	O	E	O	E			
Pass	4	3.76	13	14.09	14	13.15	31	0.15	2
Fail	0		2		0		2		
Total	4		15				33*		

*Data was invalid for 4 subjects thus reducing the sample size.
O--Observed Frequencies
E--Expected Frequencies

Table 17
Color-Vision Defective Group Performance on
The Panel D-15 Test Analyzed by Grade Level

	Kindergarten		Second		Seventh		N	χ^2	df
	O	E	O	E	O	E			
Pass	2	1.11	3	4.44	5	4.44	10	1.25	2
Fail	2		13		11		26		
Total	4		16		16		36*		

*Data was invalid for 2 subjects thus reducing the sample size
O--Observed Frequencies
E--Expected Frequencies

It was determined that for neither the control nor the color-vision defective group were there significant differences in the proportion of kindergarteners, second graders and seventh graders passing the Panel D-15 Test.

Dvorine Nomenclature Test

Further information concerning subject performance on the Dvorine Nomenclature Test was provided by analyzing the colors that were missed by various groupings of subjects. These data were analyzed for each of the six groups and for the composite sample.

A total of 767 subjects were administered the Dvorine Nomenclature Test. These included both the color-vision normal control group and the color-vision defective group plus other selected subjects. A description of the subjects taking the Dvorine Nomenclature Test is presented in Table 18. Of the 731 subjects not in the Color-Vision Defective Group, about two percent of the total failed the Dvorine Nomenclature Test and were classified as color-ignorant.

Table 18
Group Placement of Subjects
Taking the Dvorine Nomenclature Test

Group	N	Percentage
1	393	51.24
2	37	4.82
3	1	.13
4	254	33.12
5	46	6.00
6	36	4.69
Total	767	100.00

Group 1--Color-vision normal on first AO-HRR but not selected for the control group.
Group 2--Color-vision normal control group

Group 3--Color-vision normal on first AO-HRR. Randomly selected for Phase II testing and encountered problems on Ishihara 14.
Group 4--Color-vision defective on first administration of AO-HRR; not defective on second administration of AO-HRR.
Group 5--Color-vision defective on first and second administrations of AO-HRR and passed one or two of Ishihara Tests in Phase II.
Group 6--Color-vision defective group. Failed first and second administrations of AO-HRR and also failed Ishihara Test.

The data were also analyzed by the colors missed on the Dvorine Nomenclature Test by various groups of subjects. Data presented in Table 19 represents the percentage of subjects in each group which passed each color. In this analysis those colors which were passed by fewer than seventy-five percent of the subjects are identified as having possible educational relevance.

Table 19
Group Performance on the
Dvorine Nomenclature Test Analyzed
by Percentage of Each Group Passing Each Color

Color	Groups					
	1	2	4	5	6	Total
Dark Red	94.91	100.00	98.43	95.65	91.67	96.22
Dark Brown	97.71	100.00	98.43	97.83	61.11*	96.35
Dark Violet	95.42	97.30	97.64	86.96	41.67*	93.22
Dark Yellow	98.73	100.00	98.82	93.48	97.22	98.44
Dark Blue	96.44	100.00	98.43	95.65	86.11	96.74
Dark Green	97.70	100.00	99.21	97.63	86.11	97.65
Dark Gray	68.96*	89.19	80.31	67.39*	69.44*	73.66*
Dark Orange	98.73	100.00	99.61	91.30	91.67	98.31
Light Red	94.15	91.89	92.91	86.96	77.78	92.44
Light Brown	88.04	97.30	94.09	86.96	55.66*	88.92
Light Violet	95.42	97.30	98.43	86.96	66.67*	94.65
Light Yellow	98.73	100.00	99.21	93.48	94.44	98.44
Light Blue	94.91	100.00	98.82	91.30	88.89	95.96
Light Green	97.70	100.00	98.43	95.65	77.78	96.87
Light Gray	59.29*	75.68	57.84*	54.35*	38.89*	58.28*
Light Orange	93.80	94.59	92.52	95.65	72.22*	92.57

*Colors missed by more than 75 percent of the group.

Group 1--Color-vision normal on first AO-HRR but not selected for the control group.
Group 2--Color-vision normal control group.

Group 3--Not included, only one subject. See Table 7 for description.

Group 4--Color-vision defective on first administration of AO-HRR, not defective on second administration of AO-HRR.
Group 5--Color-vision defective on first and second administrations of AO-HRR and passed one or two of Ishihara Tests in Phase II.
Group 6--Color-vision defective group. Failed first and second administrations of AO-HRR and also failed Ishihara Tests.

Inspection of Table 19 indicates that both light and dark gray were very difficult for most groups with the exception of the color-vision normal control group (Group 2). Of the color-vision defective group (Group 6) more than 25 percent made errors on seven colors. These colors consisted of Dark Brown, Dark Purple (Violet), Dark Gray, Light Brown, Light Purple (Violet), Light Gray and Light Orange.

When these data were analyzed by grade level for Groups 2 and 6 the following results were obtained (Table 20).

Table 20
Dvorine Nomenclature Test Results
for Color-Vision Normal and Defective Groups
By Colors Missed and Grade Level

Colors	Group 2 Color-Vision Normal K	2	7	N	Group 6 Color-Vision Defective K	2	7	N	Total
Dark Red	0	0	0	0	1	2	0	3	3
Dark Brown	0	0	0	0	2	5	7	14	14
Dark Violet	1	0	0	1	1	9	11	21	22
Dark Yellow	0	0	0	0	0	0	0	0	0
Dark Blue	0	0	0	0	0	3	2	5	5
Dark Green	0	0	0	0	1	4	0	5	5
Dark Gray	2	0	2	4	2	4	5	11	15
Dark Orange	0	0	0	0	0	2	1	3	3
Light Red	0	1	2	3	1	3	3	7	10
Light Brown	0	1	0	1	2	7	5	14	15
Light Violet	1	0	0	1	2	2	8	12	13
Light Yellow	0	0	0	0	0	1	0	1	1
Light Blue	0	0	0	0	1	1	2	4	4
Light Green	0	0	0	0	0	4	4	8	8
Light Gray	1	4	4	9	3	9	7	19	28
Light Orange	1	0	1	2	1	1	4	6	8
Totals	6	6	9	21	17	57	59	133	154

The performance of the color-vision defective group on the Dvorine Nomenclature Test was further analyzed by comparing the performance of all those subjects in the color-vision defective group who had failed the Panel D-15 Test and those who had failed the Panel D-15 Test who were classified as severe (red-green defect) on the second administration of the AO-HRR Test with the total color-vision defective group's performance. These data are presented in Table 21.

Table 21
Performance of Color-Vision Defective Group
and Subsets of This Group on the Dvorine Nomenclature Test
Analyzed by Percentage Passing Each Color

Colors	Groups A	B	C
Dark Red	91.67	92.30	77.80
Dark Brown	61.11*	53.80*	33.30*
Dark Violet	41.67*	26.90*	0.00*
Dark Yellow	97.22	96.20	88.90
Dark Blue	86.11	80.80	66.70*
Dark Green	86.11	84.60	55.60*
Dark Gray	69.44*	61.50*	22.20*
Dark Orange	91.67	88.50	77.80
Light Red	77.78	73.10*	55.60*
Light Brown	55.66*	46.20*	22.20*
Light Violet	66.67*	57.70*	44.40*
Light Yellow	94.44	92.30	77.80
Light Blue	88.89	92.30	88.90
Light Green	77.78	69.20*	22.20*
Light Gray	38.89*	38.50*	22.20*
Light Orange	72.22*	73.10*	55.60*

*Colors missed by more than 25 percent of the group.

A--Color-Vision Defective Group (Group 6).
B--Subjects in the Color-Vision Defective Group who Failed the Panel D-15 Test.
C--Subjects in the Color-Vision Defective Group who failed the Panel D-15 Test and were classified as having a strong defect by the AO-HRR Test.

Inspection of the table (Table 21) indicates that subjects in Group C, had greater difficulty overall in naming colors. In addition to the seven colors that were missed by more than 25 percent of the color-vision defective group as a whole, Group B missed more than 25 percent of the Light Red and Light Green colors. This made a total of nine colors that were missed by this group. Subjects in Group C, the color-vision defective group, subjects who failed the Panel D-15 Test and also were classified as having a "Severe Red-Green" defect on the AO-HRR, made errors on more than 25 percent on two additional colors, Dark Blue and Dark Green. This group had a total of eleven colors on which more than 25 percent of the group made errors. These colors were Dark Brown, Dark Violet, Dark Blue, Dark Green, Dark Gray, Light Red, Light Brown, Light Violet, Light Green, Light Gray and Light Orange.

A One-Sample Chi-Square Test was used to test the significance of the difference in the number of colors missed by the color-vision normal and the color-vision defective groups. The Chi-Square Test was also employed to test the significance of difference between the number of color-vision normal and color-vision defective subjects missing each color. In only seven instances was the number of subjects missing a particular color sufficiently large to permit this test to be utilized. The results of these analyses are presented in composite form in Table 22.

Table 22
Chi-Square Summary for Colors Missed
on the Dvorine Nomenclature Test by
Color-Vision Normal and Color-Vision Defective Groups

Colors Missed	Color-Vision Normal	Color-Vision Defective	χ^2	df
Total Colors Missed	21	133	81.45**	1
Dark Brown	0	14	14.00**	1
Dark Violet	1	21	18.18**	1
Dark Gray	4	11	3.27	1
Light Red	3	7	1.60	1
Light Brown	1	14	11.27**	1
Light Violet	1	12	9.31*	1
Light Gray	9	19	3.57	1

*$p < .01$ **$p < .001$

The results of this analysis indicate that there is a significant difference between the number of color-vision normal and color-vision defective subjects missing the following colors: Dark Brown, Dark Violet, Light Brown, Light Violet. There was also a significant difference in the total overall number of colors missed by the color-vision normal and color-vision defective groups with the color-vision defective subjects missing more colors as a group.

Comparisons in Performance
As Assessed by the Test Instruments

As was indicated in the proposal, comparisons were made between performance on color-vision defectives on the AO-HRR classification, the Dvorine Nomenclature Test, the Panel D-15 Test and the Ishihara 14-Plate Edition. This analysis was conducted to determine if the types of color-vision defects classified by each were in agreement.

Failure on one or several of the color-vision tests may indicate a problem, but it may not be a color-vision problem that affects the naming of colors tested on the Dvorine Nomenclature Test. Of the seven subjects in the color-vision defective group who passed the Panel D-15 Test and took the Dvorine Nomenclature Test, one had four errors, one had three errors and the rest had two or fewer errors (Table 23).

Table 23
Number of Errors on the Dvorine Nomenclature Test
by Subjects in the Color-Vision Defective Group
Who Passed the Panel D-15 Test

Level	AO-HRR Extent and Type	Panel D-15 Results	Dvorine Nomenclature Number of Errors
Kindergarten	Mild Deutan*	Pass	2
	Mild Deutan	Pass	0
Second Grade	Unclassified		
	Red-Green*	Pass	1
	Medium Protan*	Pass	1
Seventh Grade**	Mild Deutan*	Pass	4
	Medium Deutan	Pass	0
	Mild Deutan*	Pass	3

*Subjects who were classified by the Ishihara 14-Plate as having a defect whose type (deutan or protan) was in agreement with the AO-HRR classification, but whose extent was strong on the Ishihara 14-Plate.

**Two seventh grade subjects did not take the Dvorine Nomenclature Test.

Fifteen subjects were found to have failed the Ishihara Unlettered Test who manifested a red-green (protan or deutan) type of defect. The type of defect was consistently in agreement when they were classified by the AO-HRR Test, the Ishihara Plate Test and the Panel D-15 Test. Of the subjects, thirteen, or 86.6 percent, missed five or more colors on the Dvorine Nomenclature Test (Table 24).

Table 24
Number of Errors on the Dvorine Nomenclature Test
by Subjects in the Color-Vision Defective Group Whose Type
was Consistent on the Tests in Phases I, II, and III

Level	Extent on 2nd Administration of AO-HRR	Type on AO-HRR's Ishihara 14-Plate* and Panel D-15	Number of Errors on Dvorine
Kindergarten	None	None	0
Second	Strong	Deutan	5
	Strong	Deutan	8
	Strong	Deutan	10
	Strong	Deutan	10
	Strong	Protan	8
Seventh	Mild	Deutan	6
	Medium	Deutan	1
	Medium	Deutan	4
	Medium	Deutan	5
	Medium	Deutan	7
	Strong	Deutan	6
	Strong	Deutan	7
	Strong	Deutan	8
	Medium	Protan	5
	Medium	Protan	7

*All subjects whose classification as to type was protan or deutan on the Ishihara 14 Plate had a classification of strong for extent or degree of defect.

Of the fifteen subjects, thirteen had five or more errors. This indicates that 86.6 percent of the subjects had trouble in naming five or more colors on the Dvorine Nomenclature Test.

Of the ten subjects who were found to have a severe or strong red-green defect on the second administration of the AO-HRR Test, 100 percent missed five or more colors on the Dvorine Nomenclature Test (Table 25).

Table 25
Number of Errors Made on the Dvorine Nomenclature Test by Subjects in the Color-Vision Defective Group Who Were Classified as Strong by the Second Administration of the AO-HRR

Level	Second Administration of AO-HRR Extent	Type	Number of Errors Dvorine
Kindergarten	Strong	Deutan	9
Second Grade	Strong	Deutan	5
	Strong	Deutan	7
	Strong	Deutan	10
	Strong	Deutan	10
	Strong	Protan	8
Seventh Grade	Strong	Deutan	6
	Strong	Deutan	7
	Strong	Deutan	8

In the color-vision defective group the most common type of defect was deutan with 65.6 percent of the red-green defectives in this Classification. Protan type defects were found in 10.5 percent, unclassified protan-deutan defects in 5.2 percent, and unclassified red-green defects in 18.4 percent of those with a red-green defect (Table 26).

Table 26
Frequency and Percentage of Red-Green Types of Defects as Classified by the Second Administration of the AO-HRR Test for the Color-Vision Defective Group

Sex	Group A	Average %	Group B	Average %	Group C	Average %	Group D	Average %	Total
Male	24	66.6	4	11.1	2	5.5	6	16.6	36
Female	1	50.0	0	00.0	0	0.0	1	50.0	2
Totals	25	65.6	4	10.5	2	5.2	7	18.4	38

Group A--Deutan Defects
Group B--Protan Defects
Group C--Unclassified Protan or Deutan Defects
Group D--Unclassified Red-Green Defects

Frequencies and percentages for the degree of defect among the color-vision defective group subjects are presented in Table 27.

Table 27
Frequencies and Percentages for the Extent of Degree of Red-Green Defects for the Color-Vision Defective Group As Measured by the Second Administration of the AO-HRR

Degree	Group A	%	Group B	%	Group C	%	Group D	%	Total
Mild	6	15.7	0	0	1	2.6	7	18.4	14
Medium	10	26.3	3	7.9	1	2.6	0	0	14
Strong	9	23.6	1	2.6	0	0	0	0	10
Totals:	25	65.6	4	10.5	2	5.2	7	18.4	38

Group A--Deutan Defects.
Group B--Protan Defects.
Group C--Unclassified Protan or Deutan Defects.
Group D--Unclassified Red-Green Defects.

CHAPTER IV--SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This investigation was undertaken to provide data relative to the number of kindergarten, second and seventh grade public school students classified as having color-vision defects by various instruments and combinations of instruments. In addition, the ability of both subjects with color-vision defects and color-vision normal subjects to utilize color and to name colors was investigated.

A total of 2,476 subjects from the three grade levels received color-vision testing with the AO-HRR Test. The number identified by each of several criteria was determined and comparisons were made. Those subjects identified as having color vision defects on all criteria were identified as the color-vision defective group. Thirty-eight subjects were identified as consistently demonstrating color-vision defects. A similar number of color-vision normal subjects was designated as color-vision normal and comprised the control group.

A total of 363 subjects were identified by the first administration of the AO-HRR Test as tentatively manifesting color-vision defects. These subjects were retested with the AO-HRR Test to confirm the presence of color-vision defects. Those who also failed this administration were administered the Ishihara Tests. The color-vision defective subjects consistently failed all of these tests while the subjects in the color-vision normal control group consistently passed all of the tests.

The subjects in the color-vision defective and control groups were specified by sex, grade level, and race. These variables were employed in further analyses.

As a result of the first Phase of testing, it was found that 14.67 percent of the total group had been identified as having color-vision defects. There was no appreciable difference in percentage between the racial groups or between male and female subjects. In all instances the percentage for the groups of subjects identified by the first administration of the AO-HRR was much higher than the percentage generally reported for similar populations.

When the most stringent criterion was employed, it was found that the percentage of the total sample manifesting color-vision defects dropped to 1.46. The percentage of Caucasian males found to be color-vision defective by the multiple criteria was 3.59, which was close to the percentage reported by Lampe[2] (3.0 to 3.5 percent for boys). The percentage of Black male subjects who manifested color-vision defects by the multiple criteria was significantly lower than that for the Caucasian males with only 1.55 percent being identified. The percentage of Caucasian females found to be color-vision defective by the multiple criteria was slightly lower than the percentage found in

other studies. It was found that approximately 0.24 percent of the Caucausian females had color-vision defects compared with the lowest generally reported figure for other studies of 0.69 percent. No Black females were found to manifest color-vision defects when the multiple criteria were employed.

When the criterion of failure on only one administration of the AO-HRR Test was employed, it was found that more kindergarten and second grade subjects were identified as color-vision deficient than would have been expected, while there were fewer seventh grade subjects. Failure on both the first and second administrations of the AO-HRR Test resulted in more kindergarten subjects but fewer seventh grade subjects being identified than expected.

The criterion of failure on all administrations of the three color-vision screening instruments did indicate the proportion of color-vision defective subjects at the three levels to be equal.

The color-vision defective and color-vision normal control subjects were tested to determine their ability to use color as measured by the Panel D-15 Test. It was determined that when considered as a group, significant numbers of color-vision defective subjects demonstrated an ability to utilize color. The color-vision normal subjects as a group were able to utilize color effectively with only two of the thirty-seven subjects not being able to utilize color. When the results of the two groups were analyzed by grade level, it was found that in neither instance was there a significant difference between the kindergarten, second, and seventh grade subjects in their ability to utilize color.

Subjects in the color-vision defective and color-vision normal control group, as well as other selected subjects, were also administered the Dvorine Nomenclature Test to ascertain their ability to name colors. A total of 767 subjects took this test. For the total group, the most frequently missed colors were light and dark gray. Colors missed by more than twenty-five percent of the subjects were denoted as being of possible education relevance. There were none of the colors missed by more than twenty-five percent of the subjects in the color-vision normal control group. There were seven colors missed by more than twenty-five percent of the subjects in the color-vision defective group. Subjects in the color-vision defective group who also failed the Panel D-15 Test, a measure of color usage, were found to have greater difficulty overall in naming colors. Those color-vision defective subjects who failed the Panel D-15 Test and were classified as having a strong defect in color by the AO-HRR Test were found to have difficulty with even more colors with more than twenty-five percent of the subjects missing eleven of the sixteen colors presented. The difference in performance between the color-vision normal control subjects and the color-vision defective group subjects was analyzed to determine if significant differences between the groups did exist. It was found

that significantly more color-vision defective than color-vision normal subjects missed the colors of Dark Brown, Dark Violet, Light Brown and Light Violet. There was also found to be a significantly higher number of color-vision defective subjects who had problems naming colors than color-vision normal subjects.

In an attempt to provide information as to the comparability of classifications resulting from several instruments, comparisons of type and extent of defect as assessed by the AO-HRR, Pass/Fail on the Panel D-15, and the number of errors on the Dvorine Nomenclature Test were made. It was found that of the eight color-vision defective subjects who had demonstrated an ability to utilize color on the Panel D-15, there was agreement between the Ishihara Test and the AO-HRR Test as to the type of color-vision defect for five of the subjects.

Fifteen of the subjects found to have failed the Ishihara Unlettered Test had defects which agreed with the type of defect specified by the AO-HRR Test, the Ishihara Plate Test, and the Panel D-15 Test. Of these subjects, 86.6 percent missed five or more of the colors on the Dvorine Nomenclature Test.

Of the ten subjects found to have severe or strong red-green defects on the second administration of the AO-HRR Test, all ten missed five or more colors on the Dvorine.

When the type and extent of defects manifested by color vision defective subjects were analyzed, it was determined that the most common type of defect was deutan.

Conclusions

As a result of the testing of the hypotheses presented in this investigation, as well as other related findings, the following conclusions are presented. These conclusions must be interpreted in light of the scope of the project and in particular in light of the limitations present in the study.

Hypothesis I There will be no difference in the proportion of color-vision defects present at the second and seventh grade levels.

As a result of the investigation it can be concluded that differences do exist when using the AO-HRR Test and the strict published criteria for test failure is employed. More subjects are identified as being color-vision deficient at the second grade level (and at the kindergarten level as well) than would be expected; while fewer seventh grade subjects than would be expected are identified by this criterion. When a battery of color-vision tests is employed, however, no difference between the proportion of color-vision defective subjects at the different grade levels is found.

As a result of failure on a single administration of the AO-HRR Test, a much larger percentage of all racial groups was found to be identified as having color-vision defects than is commonly cited in the literature. When multiple tests are employed, however, the percentage of subjects identified as having color-vision d ' cts drops to levels which more closely approximate the results of other similar studies involving school populations (Table 14). The percentage of white male subjects was found to be somewhat lower than the frequently reported figures of five to eight percent for adult populations. The utilization of multiple criteria also resulted in identification of a significantly lower percentage of Black subjects manifesting color-vision defects than was found for Caucasian subjects. No Black female subjects were found to manifest color-vision defects when multiple tests were employed.

When a single administration of the AO-HRR Test is employed using the criterion for failure of errors made on any one plate of the test, a nearly equal percentage of male and female subjects are identified as having color-vision defects. When compared with the results of similar studies of color-vision defects cited in the literature, not only is the overall percentage of color-vision defects higher but there is also a far higher percentage of female subjects identified. This tends to support the conclusion that employing this test and its prescribed scoring criteria as the sole measure of color-vision defect, leads to assessment of factors other than color-vision. Use of multiple color-vision tests results in a percentage of subjects being identified as color-vision defective which closely approximates previously reported results. It may thus be concluded that the use of the AO-HRR Test when the criterion of failure is errors on any single plate, results in a very liberal classification of subjects as color-vision defective with this population. It may also be concluded that use of the battery of tests employed in this study results in identification of a percentage of subjects with color vision defects which is much more in line with the results of other similar studies. This indicates the multiple tests result in a more conservative classification of subjects as color-vision defective with this population.

In light of subject performance on the AO-HRR Test when compared with subject performance on the battery of tests, it can be concluded that some factor or factors other than color-vision is measured by the AO-HRR Test when the published scoring criterion is employed with this population.

Hypothesis II. Some of the subjects in the color-vision defective group will be able to utilize color as measured by the Panel D-15 Test.

Color-vision defective subjects, as a total group, demonstrated that regardless of their deficiency, significant numbers of them were able to utilize color as measured by the Panel D-15 Test. It may thus be concluded that some color-vision defective subjects have developed compensatory techniques or that their defects are of a type and/or degree such as to permit them to perceive color to an extent that it is possible for them to name most colors.

Hypothesis III. All of the subjects in the color-vision normal group will be able to utilize color as measured by the Panel D-15 Test.

The color-vision normal group indicated no significant degree of failure to utilize color as measured by the Panel D-15 Test. The results of some of these subjects were, however, invalid on the Panel D-15 Test. Some of the second grade subjects who were classified as color-vision defective, performed in such a manner that their results were borderline both as to the classification of pass and as to type of pass. This indicates that some younger color-vision defective subjects had difficulty with the Panel D-15 Test. These subjects also were found to exhibit no failures on the Dvorine Nomenclature Test involving the naming of colors.

Hypothesis IV. Some of the color-vision normal subjects will manifest color-ignorance as measured by the Dvorine Nomenclature Test.

As a result of color-vision normal subject performance on the Dvorine Test, it can be concluded that age does not appear to be a factor in the performance of younger and older subjects on this test. It can also be concluded that subjects who consistently demonstrated normal color-vision and were placed in the color-vision normal control group, were not ignorant of colors at any of the grade levels sampled.

Other Conclusions

The classification of extent (medium or strong) on the Ishihara 14-Plate Test does not appear to be as helpful in identifying subjects who have difficulty using color as does the classification of extent (mild, medium, or strong) on the AO-HRR Test. The Ishihara 14-Plate Test classification of extent was not useful in identifying color-vision defective subjects who were having problems using color, while the AO-HRR classification of strong identified the subjects who missed five or more colors on the Dvorine Nomenclature Test.

Although no significant difference was found between the grade levels on the Pass/Fail results of the Panel D-15 Test, further study of the type of failure made on the Panel D-15 Test may reveal that some of the younger subjects who failed the test had different kinds of problems than were exhibited by the older subjects. This conclusion is based on the fact that a number of the younger subjects who failed the Panel D-15 did not fail the Dvorine Nomenclature Test and made no more errors than the color-vision normal students made. A review of the results (Tables 8, 15, 16, 18, 21, 22) supports this conclusion. The sixteen subjects who were classified as strong on the AO-HRR Extent or were consistently the same type on both administrations of the AO-HRR, the Ishihara 14-Plate and the Panel D-15 Test made a total of 106 errors on the Dvorine Nomenclature Test. Of the ten subjects in the color-vision defective group who passed the Panel D-15 Test, the eight who took the Dvorine Nomenclature Test made a total of eleven errors on the Dvorine Test. The ten subjects in the color-vision defective group whose type was not consistently the same, who did not have a strong

defect and who failed the Panel D-15 Test, made a total of sixteen errors on the Dvorine Nomenclature Test. Two of the ten were in kindergarten, nine were in second grade, and one was in seventh grade. This indicates that younger subjects at the second grade and kindergarten levels may experience problems with the Panel D-15 Test that older subjects do not have. (from the AO-HRR)

Recommendations

General Recommendations

As a result of the findings and conclusions of this investigation, the following recommendations are made.

The Inter Society Color Council's Subcommittee on Color Blindness was the group that approved the published criteria for pass-fail on the AO-HRR Test and the classifications for the various types and extents of color-vision defects. It would appear advisable that a re-evaluation of the criteria for pass-fail on the AO-HRR Test be undertaken and the new criteria made available for those who are currently using the test. Ophthalmologists, optometrists, and other doctors using the AO-HRR Test are able to use their clinical judgments and thus avoid problems of mislabeling due to subjects making errors on only one plate; namely, Plate 3. Similar standards should be available for others who test children to avoid over referrals.

For the personal benefit of the students identified as being color-vision defective by all criteria (the color-vision defective group), it is recommended that a full clinical examination should be made available because there were a number of cases in which the test results were not conclusive. The subjects should not be labeled color-vision defective without a full clinical evaluation.

It is also recommended that further investigations of the subjects who failed the color-vision tests be undertaken to evaluate factors other than color-vision defects that may be affecting the results of certain younger subjects whose tests do not yield consistent results. Such an investigation could evaluate the subjects' performance on various tests (for example, tests of visual perception and other perception tests as deemed suitable) to determine if these subjects had any problems in these areas. Because many perceptual problems tend to dissipate as subjects mature, such a study should be undertaken within the 1972-73 school year.

Another factor to consider in such an evaluation might be the effects of student to student transmission of information concerning the tests employed. Seventh graders may also, be more test sophisticated than younger subjects, and/or seventh grade subjects may be more practiced at reading cues unconsciously given by the examiner in the course of the testing.

It is recommended that further analysis of existing data be undertaken to determine if differences of a significant magnitude exist between grade levels on the Panel D-15 evaluation of type. Some younger subjects' type of color-vision defect was unusual and it was not possible to diagnosis the type using the published standards.

Recommendations for Further Study

In addition to recommendations concerning the results of the investigation, additional areas of investigation are recommended.

Earlier investigations (Thurline) which have been undertaken with small numbers of Black subjects have not indicated any differences existed in the prevalence rate of color-vision defects among Black and Caucasian subjects. In the current investigation, it was found that significantly more Caucasian male subjects manifested color-vision defects than did Black male subjects. This study, however, included only 386 Black males as compared to 836 Caucasian males. It is recommended that studies be undertaken employing larger Black samples of subjects to determine if the percentages of color-vision defective Black males continue to increase as the sample size increases.

Because the AO-HRR Test has been discontinued for the present time due to printing costs, further studies need to be undertaken to examine other mass screening devices.

Additional investigations employing larger samples need to be undertaken to establish the usefulness of the Ishihara Tests. These tests were administered to less than 120 subjects in the current investigation. The Ishihara 8-Plate Unlettered and the Ishihara 14-Plate Tests were failed by all of the members of the color-vision defective group. The Ishihara 14-Plate Test did not separate these subjects into mild and strong as all subjects who were either protan or deutan were classified as strong.

It is recommended that a study encompassing much larger numbers be undertaken to assure a large enough number of color-vision defective subjects to enable more extensive comparisons to be made between various types and degrees of color-vision defects.

Future studies should be undertaken to determine the usefulness of the Panel D-15 Test. Only a small number of subjects were tested with the Panel D-15 Test in this study.

It is further recommended that in future studies, provisions should be made to familiarize subjects with the skills required for performance on the Panel D-15 Test. There should also be provisions for additional administrations of the Panel D-15 Test when the results as to both the type of defect and the pass/fail classifications are questionable.

Additional investigations should be undertaken to determine if younger subjects have different types of problems with the Panel D-15 Test than the older subjects. This investigation should also determine what types

of problems the younger subjects experience that would result in failure on the Panel D-15 Test but cause them to miss very few colors on the Dvorine Nomenclature Test.

Finally, it is recommended that the publication of a set of standards for performance on the Dvorine Nomenclature Test be undertaken. This would necessitate a series of studies to determine the basis for such standards.

REFERENCES

REFERENCES

1. Thuline, H.C. Color-vision defects in American school children. Journal of the American Medical Association, CLXXXVIII, May 11, 1964, pp. 514-518.

2. Lampe, J.M. An evaluative study of color-vision tests for kindergarten and first grade pupils. Presented at the Annual Meeting of the American Health Association (42nd Meeting, Detroit, Michigan, November 9, 1968).

3. Prater, M.J. Color Uses in Primary Instructional Materials and Possible Implications for Color Deficient Children. Unpublished Doctoral Dissertation, George Peabody College for Teachers, Nashville, Tenn., 1967.

4. Linksz, A. A short primer on color vision and its defects. Journal of Pediatric Ophthalmology, V, Aug. 1968, pp. 183-190.

5. Betts, E.A. Foundations of Reading Instruction. American Book Company, New York, 1946, pp. 133-135.

6. Russell, D.H. and Others. My Do and Learn Book to Accompany The Little White House. Ginn and Company, Boston, 1957, p. 91 (as quoted in Prater[3]).

7. Randall, J.H. and Others. Learning to Use Arithmetic, Book III. D.C. Heath and Company, Chicago, 1962, p. 11 (as quoted in Prater[3]).

8. Linksz, A. An Essay on Color Vision and Clinical Color-Vision Tests. Grune and Stratton, New York, 1964.

9. Wildman, P.R. Teacher Awareness of Color Deficiency and Its Effect on Instruction in the First Grade. Unpublished Doctoral Dissertation, George Peabody College for Teachers, Nashville, Tenn., 1964.

10. Mercer, M. Your Child in This Colorful World. Association for the Blind and for Sight Conservation, Grand Rapids, Michigan, 1948.

11. Monroe, M. and B. Rogers. Foundations for Reading. Scott, Forseman and Company, Chicago, Illinois. 1964 (as quoted in Prater[3]).

12. Linksz, A. The Farnsworth Panel D-15 Test. American Journal of Ophthalmology, LXII:1, July 1966, pp. 27-37.

13. Parente, L. and M.T. Coady. Study of color blindness in selected Hamden elementary schools. Connecticut Health Bulletin. Connecticut State Department of Health, LXXVII, Dec. 1963, pp. 321-323.

14. National Society for the Prevention of Blindness. Color-vision. Sight Saving Review, XXIX, Winter 1959, pp. 197-202 (as quoted in Prater[3]).

15. Murray, E. Review of Farnsworth Dichotomous Test for Color Blindness: Panel D-15. In Buros (Ed.) Fourth Mental Measurement Yearbook. Gryphon Press, Highland Park, N.J. 1953, p. 654.

16. Mandola, J. The role of color vision anomalies in elementary school achievement. The Journal of School Health, XXXIX:9, November 1969, pp. 633-636.

17. Schmidt, I. Personal Communication with the Principal Investigator, 1971.

18. Shearron, G.F. The Reading Efficiency, Socio-Economic Status, and Intelligence Quotient of Color Deficient Children. Unpublished Doctoral Dissertation, George Peabody College for Teachers, Nashville, Tenn., 1964.

19. Ferguson, G.A. Statistical Analysis in Psychology. McGraw-Hill, New York, 1959.

20. Siegel, S. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill, New York, 1956.

21. Dvorine, I. Dvorine Pseudo-Isochromatic Plates. Nomenclature Tests. Waverly Press, Inc., 1955.

22. Ishihara, S. Tests for Colour Blindness (Thirty-Eight Plates). 12th Edition, Kanehara Shuppan Col, Ltd., Tokyo, 1957.

23. Crone, R.A. Quantiative diagnosis of defective color vision. American Journal of Ophthalmology, LI, February, 1961, pp. 298-305.

24. Mandola, J. Personal Communication to the Principal Investigator, 1970.

25. Ishihara, S. Ishihara's Tests for Colour-Blindness (Fourteen Plates). Concise E., Isshinkai Foundation, Tokyo, 1970.

26. Hardy, H.L., G. Rand, and M.C. Rittler. H-R-R Pseudo-Isochromatic Plates, A Manual. American Optical Corporation, Buffalo, New York, 1957.

27. Shaffer, L.F. Review of Dvorine Nomenclature Test and Pseudo-Ishchromatic Test. In Buros (Ed.) Fifth Mental Measurements Yearbook. Gryphon Press, Highland Park, N.J., 1959, p. 837.

28. Linksz, A. Color Vision Tests in Clinical Practice. Presented at the Meeting of the American Academy of Ophthalomologists and Otolaryngologists, Las Vegas, Oct. 6, 1970.

29. Linksz, A. Personal Communication with the Principal Investigator, 1970.

30. Abarbanel, A. Problems of color-blind people. Science Digest, XLIX, June 1961, pp. 69-73.

31. Isshinka Foundation. Ishihara's Design Charts for Colour-Blindness, Unlettered Persons. San-Ei Printing Co., Ltd., Kokyo, 1970.

32. Jones, J.D. (Ed.). Profile of the Grand Rapids Public Schools. Grand Rapids Public Schools, Grand Rapids, Michigan, 1971.

33. Department of Education, State of Michigan. Enclosure in: 1971-72 Educational Assessment Program--District and School Reports. Lansing, Michigan, 1972.

34. Macbeth Sales Corporation. AO-HRR Pseudoisochromatic Plates, Bulletin No. 234. Macbeth Corp., Newburgh, N.Y.

35. Courtney, G. Personal Communication with the Principal Investigator, 1971.

APPENDIX I

Examples of Color Used to Aid in Teaching of Concepts or Skills

Examples of Color Used to Aid
in Teaching of Concepts or Skills

Examples from a first grade reading workbook[1]

See the wheat now?
Color the wheat green here.
Put a yellow X on the barn.

Put a red X on the train.
Put a blue X on the barn.
Put a green X on Susan's toy.

Examples from a third grade arithmetic workbook[2]

Color one half or Circle C red.
Color one third of Circle B blue.
Color one fourth of Circle A green.

[1]Russell, D.H. and O. Ousley. My Do and Learn Book to Accompany The Little White House. Ginn and Co., Boston, 1957, p. 91 (as quoted in Prater).

[2]Randall,J.H. and Others. Learning to Use Arithmetic, Book III. D.C. Heath and Co., Chicago, 1962, p. 11 (as quoted in Prater).

APPENDIX II

Description of Instrumentation and Special Materials Employed

DESCRIPTION OF INSTRUMENTATION AND SPECIAL MATERIALS EMPLOYED

Ishihara Test for Color Blindness

The Ishihara Test for Color Blindness employs pseudo-iso-chromatic plates to assess the presence and type of color-vision defect. The plates employ colors so chosen as to appear alike in certain types of color-vision defects, while appearing different to the person with normal color vision. Each plate consists of a printed circular pattern with a number or figure of a different color on it. The circular pattern, or background, consists of dots or discs of one color while the number or figure on the background is of another color. The colors and chroma values of the discs in both the background and figure vary from plate to plate depending on the type of color vision to be assessed.

The following is a description of the Ishihara plates as reported by Arthur Linksz in An Essay on Color Vision.[8]

In group I the digits are composed of bluish-red and yellowish-red discs while the background discs are bluish green and yellowish green. The chroma and the value of these discs are variegated. To the normal subject this arrangement presents a certain, predominantly reddish digit (say, an "8") easily seen against a predominantly greenish background. However, . . . protan (red deficient) subjects might also recognize these digits. To them all predominantly reddish dots are darker, all predominantly greenish dots lighter. Protan subjects might therefore see the same figure as the normal subject. Deuteranopes (green defective), on the other hand, with their more or less normal luminosity distribution fail to see this digit. To them the yellowish-red and the yellowish-green discs are undistinguishable. They are all yellow and make up a yellow background while the remaining bluish-red and bluish-green dots appear bluish and together form a bluish digit (say, a "3"). The plates in group I trap, as we can see, deutans only.

In group II the red-containing discs (blue-reds and yellow-reds) form the background, the green-containing discs (blue-green and yellow-greens) make up the figure. The normal subject again sees a certain digit which to him consists of mainly greens. The red-and-green defective once more sees a bluish digit on a yellowish background, but not the same digit. Plates of group II are failed by all red-and-green defectives.

In group III the digits are formed by yellow-red discs on a background of yellow-green (and scattered blues). These plates are really pseudo-isochromatic in the strictest sense of the term. The digits vanish (are not present) for the red-and-green defective to whom all of the discs are predominantly yellow (with some blue ones interspersed in an irregular pattern).

In group IV the digits consist of blue-green discs on a background of blue-red. These digits too should vanish to a red-and-green defective

Ishihara Test for Color Blindness (Continued)

to whom all dots should appear predominantly blue. Deuteranomalous subjects are not always detected by these plates.

Group V contains some interesting an quite intriguing hidden digits which supposedly only the color blind can readily see.

Plates of Group VI are to differentiate the two subtypes of red-and-green deficiency. They contain two digits. One of these digits is made up of red discs, the other of red-purple discs, and the background is gray.

American Optical H-R-R Pseudoisochromatic Plates

The following description of this instrument is based upon literature[34] from Macbeth Sales Corporation, distributors of the Macbeth Easel Lamp.

The AO H-R-R test is pseudoisochromatic in that individuals with defective color vision of the different types and extents will be unable to differentiate between the colored symbols and the grey backgrounds on certain of the test plates. To the color deficient individual a page may appear to be composed totally of grey discs while to the person with normal color vision very definite colored symbols will be seen against a grey background.

The basic pattern, as to size and location of discs, is exactly reproduced on each plate. Certain of the discs are printed in neutral gray inks which vary in brightness. These grey discs form the background pattern of the individual plate. The remaining discs on each plate are printed in several colors so as to form one or two simple geometric symbols per plate. The symbols are a circle, cross, and triangle which are familiar to everyone, including illiterates and children. The use of such symbols allows the test to be administered with the plate held in any orientation desired. In addition, certain plates vary, from book to book, in their orientation within the book. All these factors result in a test which has no clues for memorization or coaching. The test book starts with four demonstration plates, visible even to the color deficients, which serve to point out the three types of symbols which may be seen during the test and the fact that two, one or none of them may be observed on any one plate, also that the symbols may appear in any quadrant.

The screening portion of the test is composed of just six plates. These six plates which differentiate between red-green deficients, blue-yellow deficients, and those with normal color vision are able to be presented in a matter of seconds and for the great majority of subjects this completes the test. Those subjects who, in the screening test, are found to be red-green deficient are presented with ten additional test plates. Those who are found to be blue-yellow deficient are given four additional test plates. These additional plates administered only to the color deficients provide an estimate of the extent of the deficiency as mild, medium, or strong and allow the subject to be classified as to type of defect, i.e. a "Protan" differentiates greens and red-purples from grey but confuses reds and blue-greens with grey. A "Deutan" differentiates reds and blue-greens from grey but confuses

AO H-R-R (Continued)

greens and red-purples with grey. A "Tritan" differentiates blues and yellows from grey but confuses violets and yellow-greens with grey. A "Tetartan" differentiates violets and yellow-greens from grey but confuses blues and yellows with grey. A simple score sheet which accompanies the test includes interpretation directions.

Dvorine Pseudo-Isochromatic Plates, Second Edition

For purposes of this study only the Nomenclature subtest of the Dvorine Pseudo-Isochromatic Plates was employed. This color-naming test consists of a revolving nomenclature chart comprised of a 1-inch circular exposure-window which exposes in turn each of eight saturated colors and tints. This test helps to identify those subjects who are color ignorant. The test contains several features which are designed to thwart malingering subjects.[27]

Farnsworth Panel D-15

The following material was taken from the 4th Mental Measurements Yearbook edited by Buros.[15]

Test material consists of 15 3/4-inch black caps, each exposing a 1/2-inch disc of color, with a single fixed reference cap, in a 14-inch rack. The task is to arrange the caps in order by color. The colors used are chosen from the 20 standard Munsell hues of the color circle, and are of medium and uniform chroma and brightness (value), thus eliminating the cues ordinarily used by color deficients to discriminate and name colors. Scoring is facilitated by numbers of the reverse of the caps, and analysis blanks e provided on which the order of arrangement may be plotted on a color circle. Minor transpositions are normal, but cross transpositions, such as confusion of red and green, count as serious errors and score failure.

Description of Ishihara's Design Charts for Color-Blindness, Unlettered Persons

The Ishihara Unlettered 8-Plate Test is described by the authors of the text in the following manner:

This series of plates is provided to detect colour blindness in person[s] 4 to 6 years of age or in persons who can not read.

It is important for their further education and for occupational reasons to detect a deficiency in colour vision at an early age. Although several rather complicated apparatuses and plates are now available to detect or classify colour blindness quite accurately, these may not always be practicable. Since the examinees may not be able to understand complicated pieces of apparatus or read letters, the present plates are designed with simple geometrical shapes such

as circles, squares, and curved lines. (Ref. 31, p.1)

The preliminary work with the Ishihara Unlettered Test revealed that the small black x's that marked the beginning and ending points of the curved lines provided visual clues. Adult color-vision defective subjects, ophtholmologists and optometrists agreed that covering the pages with white paper to reveal only the colored design not only eliminated the problems of the clues but also provided a way to keep the pages clean.

It should be noted that the brush provided with the test is too short to be used by young children. The plates are to be 20 to 30 inches from the subject's eyes. Young children often need a brush that is 12-16 inches long to enable them to reach the plates in the test book.

Materials

Brushes Extra long brushes were needed to allow the smaller subjects to comfortably trace the symbols in the test books. The test books were placed at a distance of 30" from the subject's eyes. It was found that 11-inch to 16-inch brushes could be used satisfactorly.

Dual Purpose Rack This rack was used to hold the brush to keep it from rolling off the table. The rack was also a helpful reminder for younger subjects who tended to wave a brush around if there is no set pattern for handling the brush established. The Dual Purpose Rack was also used to stabilize the Panel D-15 Test box. Placing the rack up against the base of the easel section of the Macbeth Easel Lamp provided a stable resting place for the Panel D-15 and tended to overcome the problem of the box tipping over.

Net Covers Nylon Net Covers were used to protect the filter on the Macbeth Easel Lamp when the lamp was being carried.

Escutcheon Pins (Wire Nails) Brass 1/2" escutcheon pins (#18) were used to replace some of the shorter nails that tended to fall out of the Panel D-15 box.

Blank Page Inserts Special blank page inserts were used with the Ishihara's Tests for Colour-Blindness (Fourteen Plates). The inserts made it possible to expose only one page at a time to avoid confusion and to limit the time each plate was exposed.

APPENDIX III

Description of the 1971-72 Socio-Economic Status Measures[33]

Description of the 1971-72 Socio-Economic Status Measures[33]

The 1971-72 educational assessment program was conducted without administering a pupil background questionnaire. During the first two years of the program a pupil background questionnaire had been used to develop a schoolwide measure of socioeconomic status (SES) and to assemble measures of pupil attitudes toward school, toward achievement and toward themselves. The pupil background measure was not used in 1971-72 because (1) the SES measure had drawn severe criticism, mainly because of the personal nature of the questions asked; and (2) inadequacies were found in the attitude measures which could not be remedied in the time available.

Although the staff was in agreement that there was a demonstrated need for a measure of SES in the assessment program, there was reason to doubt that the program could survive the growing opposition to continued use of the questionnaire. Therefore, an alternate measure of SES was developed relying upon (1) the SES measure given in 1970-71, (2) the principal's questionnaire completed in January of 1972 and (3) other variables reported at the school level.

District SES measures were obtained by averaging the 1970-71 fourth and seventh grade districtSES scores. In a single year a district is unlikely to experience a marked change in its SES. Furthermore, fourth and seventh grade SES scores can both be considered as estimates of the SES level in the district. Therefore, by averaging the fourth and seventh grade means a fairly stable measure of district SES could be obtained.

In developing an SES measure for a school the principal's answer to question 13 on the Principal's Questionnaire was first consulted. If the principal indicated that the average socioeconomic status of the pupils attending the school changed very little or not at all since the previous year, the previous year's SES score was carried forward. But if the principal indicated that the SES had changed (or if there was no SES score for the school in the precious year), an estimate of the school's SES was printed in parentheses immediately after the SES score on the Local School Report (see code list on reverse side for interpretation).

In estimating the SES for any school, consideration was given to the principal's estimate of fathers' educational levels, occupational levels of parents, average annual family income, average cost of housing, and percent of students who remained in the school through the year. Also considered was the school's average score in word relationships. At the fourth grade only, consideration was also given to the percent of pupils from family units where one parent is not living in the home, the school's average score in reading, and percent white. At the seventh grade only, consideration was given to average density of occupancy of housing, percent of pupils from families on AFDC or welfare, average salary of teachers, and average experience of teachers.

The selection of predictors and the weight given to each was determined by an analysis of the questionnaire responses and scores of schools whose principals in 1971-72 judged the SES to have changed little or not at all.

The resulting multiple correlation between estimated SES and actual 1970-71 SES was .87 for the 1426 schools included in the fourth grade analysis and .89 for the 495 schools included in the seventh grade analysis.

The SES score reported for schools and districts included in the 1971-72 assessment is the best estimate of SES that could be derived from the data available. It is of course imperfect and should be used with caution.

CODING SYSTEM FOR REPORTING SCHOOL BUILDING SES SCORES

Code	Explanation
1	The reported figure is the 1970-71 value. The principal indicated no change in SES.
2	The reported figure is a new SES estimation. The principal indicated no change in SES, but there was no 1970-71 value available.
3	No building SES figure is recorded because the 1970-71 score was not available nor was there enough data to estimate a new figure. The principal had indicated no change in SES levels.
4	The reported figure is a new SES estimation based upon the principal's indication that a change had occurred in SES level.
5	The reported figure is the 1970-71 value. The principal indicated a change had occurred but there was insufficient data to compute a new value.
6	No building SES figure is recorded because the 1970-71 score was not available nor was there enough data to estimate a new figure. The principal had indicated a change in SES levels.
7	The reported figure is the 1970-71 value. The principal's 1971-72 questionnaire was not available.
8	No building SES figure is recorded because there was no 1970-71 data and no 1971-72 principal's questionnaire.
9	The reported figure is the 1970-71 value. The principal indicated an increase in SES level but the new calculation of SES was equal to or lower than the 1970-71 value.
10	The reported figure is the 1970-71 value. The principal indicated a decrease in SES level but the new calculation of SES was equal to or higher than the 1970-71 value.
11	The reported figure is a weighted average of a fourth and a seventh grade SES score derived by any combination of codes 1,2,4,5,7,9 and 10.
12	The reported figure is the SES score available from either the fourth or seventh grade of a school containing both grades but for which only one grade level SES score was available from codes 1,2,4,5,7,9 or 10.

APPENDIX IV

Summary of the Socio-Economic Status Data as Derived for the Grand Rapids Public Schools

Summary of the Socio-Economic Status Data as Derived for the Grand Rapids Public Schools

School & Level	Percentile Ranking
A -K,2	81 - 99
B -2	1 - 20
C -2	21 - 40
D -K,2	21 - 40
E -2	1 - 20
F -K,2	81 - 99
G -2	1 - 20
H -K,2	1 - 20
I -2	21 - 40
J -K,2	1 - 20
K -K,2	81 - 99
L -2	1 - 20
M -K,2	41 - 60
N -2	21 - 40
O -K	Missing
P -2	Missing
Q -2	81 - 99
R -2	1 - 20
S -K,2	81 - 99
T -K,2	21 - 40
U -2	21 - 40
V -2	81 - 99
W -7	21 - 40
X -7	61 - 80
Y -7	21 - 40
Z-2	81 - 99

APPENDIX V

Objectives of
the Training Program for the Examiners

Objectives of
the Training Program for the Examiners

The purpose of the training program for the examiners was to train the school health nurses in order to enable them to:

1) Administer the color-vision screening tests under controlled conditions.

2) Score the AO-HRR Test quickly and accurately.

3) Utilize special data processing techniques.

4) Control the numerous variables that affect color-vision testing.

5) Develop an understanding of the problems connected with color-vision testing that would allow them to be flexible and to be checked to determine if they could respond adequately in various types of problem situations.

APPENDIX VI

Example of Criterion Performance

Exemple of Criterion Performance

Explanation of "Observer & Check Sheet" for specifying criterion performance when used to check-out examiners.

The "Observer & Check Sheets" were used in training and in checking out the examiners. During the training, a simulated testing of various types of color-vision defects was provided with observers watching to record comments so as to provide written feedback at the end of the simulated situation. During the Check of the examiner, various types of defects were simulated to observe the examiners' ability to follow the special procedures necessary for various types of testing problems. When the examiner was able to successfully complete the various tasks involved, she was ready to begin testing.

SAMPLE OBSERVER & CHECK SHEET
for AO-HRR (Initial Testing & Screening)

_____Observer Problem #_____ Time_____

_____Examiner Book #_____ Date_____

If o.k. check here	Steps to Observe	If Problems, Comment Below:
	Book in place (closed) Right side up	
	Lamp on	
	Brush on rack	
	Greet Student, "Hello, I'm _____, may I have your slip?"	
	Take slip Ask then to sit down	
	Fill in data form (1st page) varifying information with student	
	Fill in top of AO-HRR Data Sheet: Examiner's name Date Book used Does subject have glasses on? If yes, 1. ask if they are tinted 2. ask then to hold them against white paper to check, regardless of reply.	

If o.k. check here	Steps to Observe	If Problems, Comment Below:
	Time Check subjects distance from book with cord Younger Subjects: Pretest Show shapes and ask one at a time what they could call them. Mark score sheet. Show small cards with 1,2,3 and no squares asking how many are there for each card. Score sheet to indicate ok, or problems. (Note: if problems exists use cards during testing). Explain that "You will be shown colored shapes like the ones on the cards and some pages will have several shapes, some will have only one, and some will have none (show cards with shapes to older subjects at this point). "I am going to show you some colored shapes in this booklet. As I turn to the page, you are to tell me first how many you see? Ready?" (Turn to Demonstration Plate 1 and ask) "How many do you see?" "What do you see?" (If necessary on Demonstration plates explain, "Now tell me how many shapes you see." "Trace." (If necessary explain "Trace the shapes you see."). "Ready?" (Turn to Demonstration plate 2) "How many do you see?" Record Response "What do you see?" Record Response "Trace" Record Response	

If o.k. check here	Steps to Observe	If Problems, Comment Below:
	Repeat these steps with rest of Demonstration plates Note: Is the score sheet at a slant so the subject cannot see it and so the the subject cannot see the type of notations made? Did the examiner proceed smoothly from one section to the next? Did the examiner proceed in the correct order? Check the order used by the examiner and indicate below the order and the sections used, by placing a number in front of each section used in the order it was done. __ Show shapes __ Pretest __ Demonstration Series __ Schedule for Malingering or Aberrant Subjects __ Screening Series __ Diagnostic Series I __ Diagnostic Series II __ Repetition of Screening Series Used tabs to turn pages Did not touch pages, or colored plates Did not let subjects touch colored plates except with special brush.	
	Remember: Do not leave book open Return book to case at end of day's testing Avoid facial and verbal expressions that will cue the subject	

APPENDIX VII

Description of the Pretest

Description of the Pretest

The pretest was designed to establish communication with the younger subjects, to see if the subjects could verbally name the shapes found on the AO-HRR Test, and to ascertain the subject's ability to respond to configurations representing one, two, three and none. These skills are needed to take the AO-HRR Test in the standardized manner. Cards depicting the symbols and configurations were shown to the subject.

Those subjects who were not able to accurately verbalize consistent responses on the Pretest were encouraged to use the cards to indicate to the examiner what responses they wished to make on the AO-HRR Test.

Subjects who had no problems with the Pretest, but who appeared to hesitate during the diagnostic series, were also encouraged to use the cards to assist them in making responses.

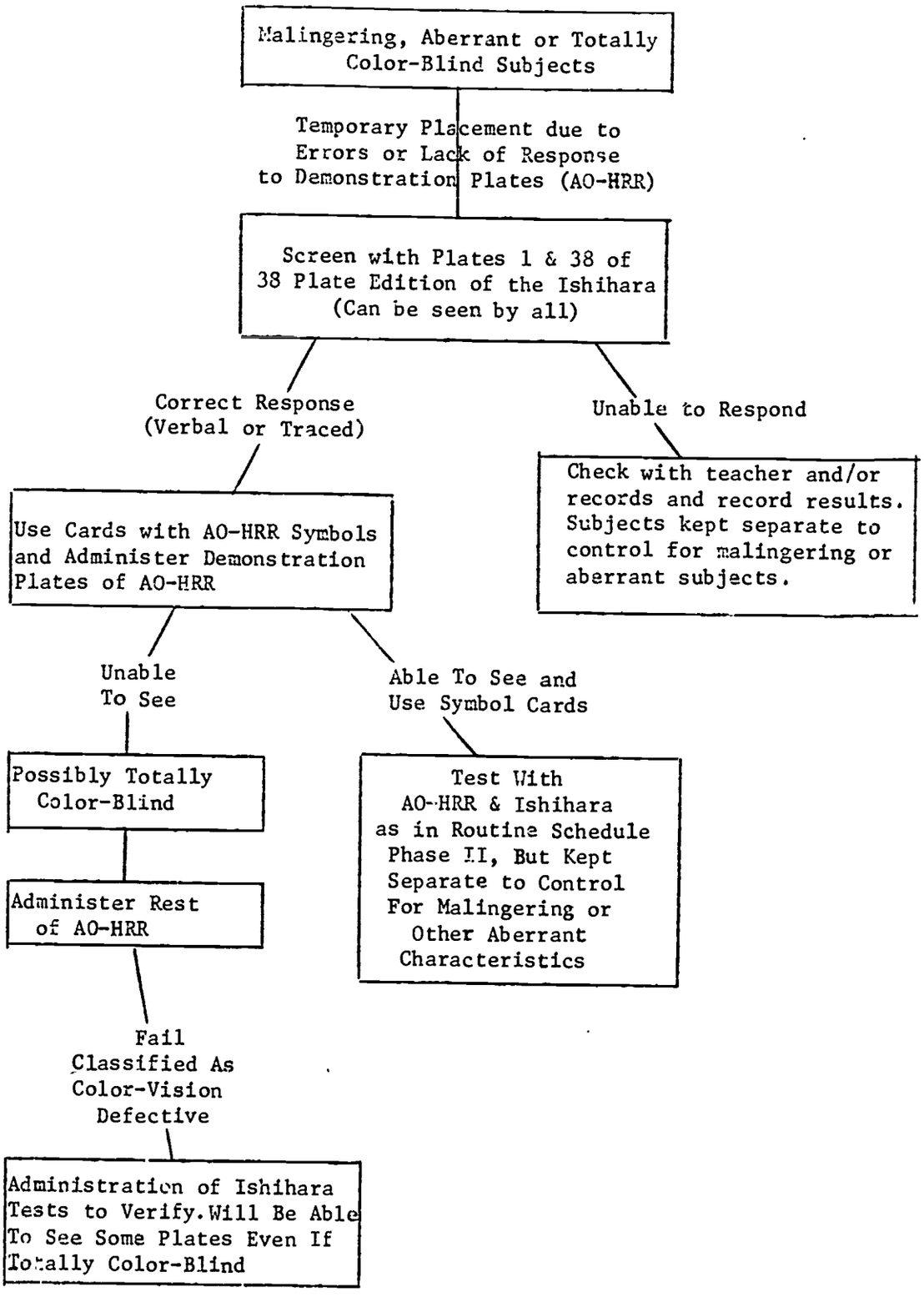
It should be noted that the subjects' response to the shapes could vary. For example, they might call O a ball, a circle, an "O", etc. Any of these responses were acceptable. The subjects could also respond to the configurations representing numbers by holding up the correct number of fingers.

The Pretest was administered to the younger subjects prior to the administration of the Demonstration Series which is the first group of plates on the AO-HRR Test.

APPENDIX VIII

Alternant Schedule for Malingering, Aberrant, or Totally Color-Blind Subjects

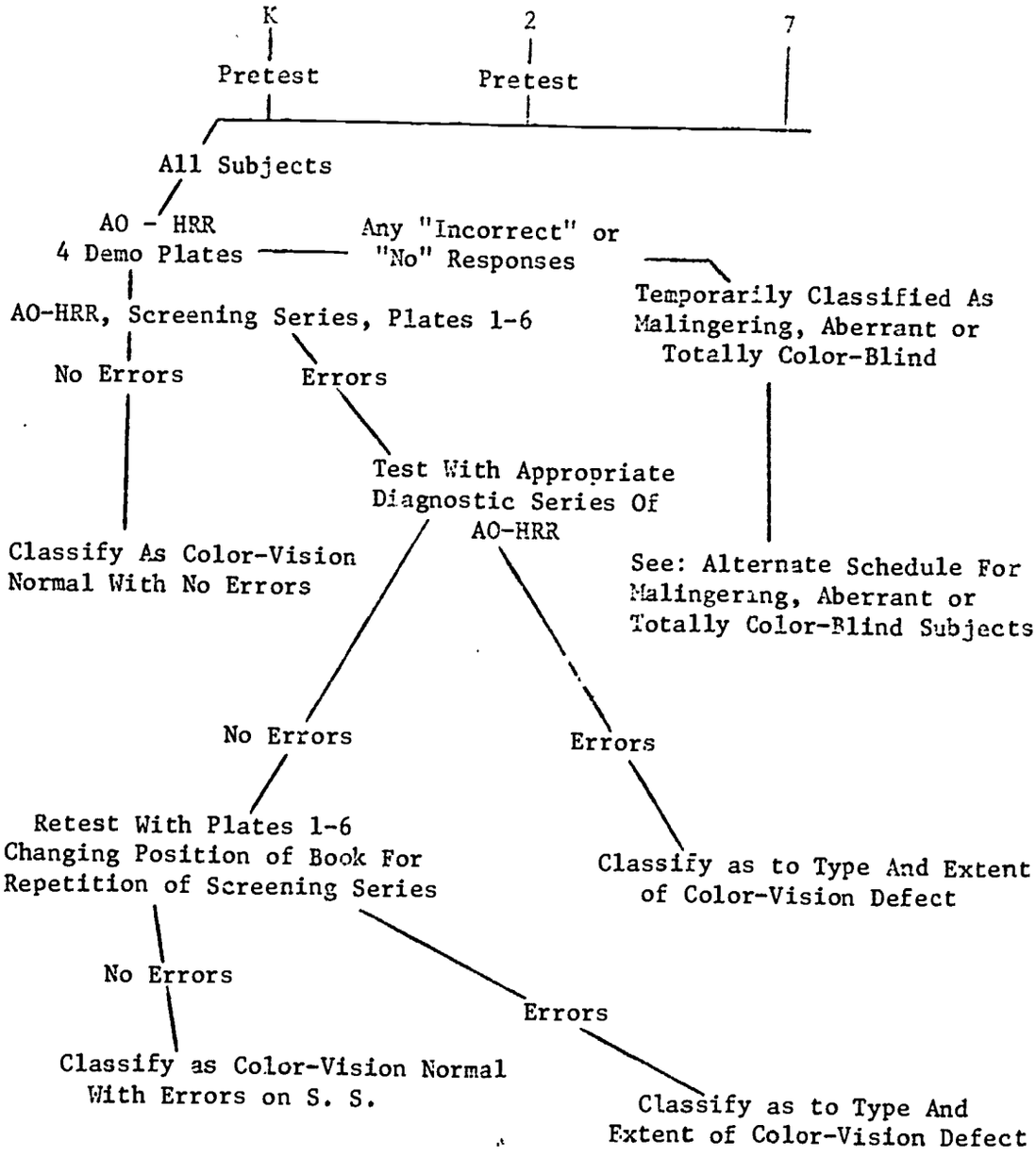
Alternate Schedule for Malingering, Aberrant, or Totally Color-Blind Subjects



APPENDIX IX

Phase I of Color-Vision Testing Initial Testing & Screening - 1st Administration of AO-HRR

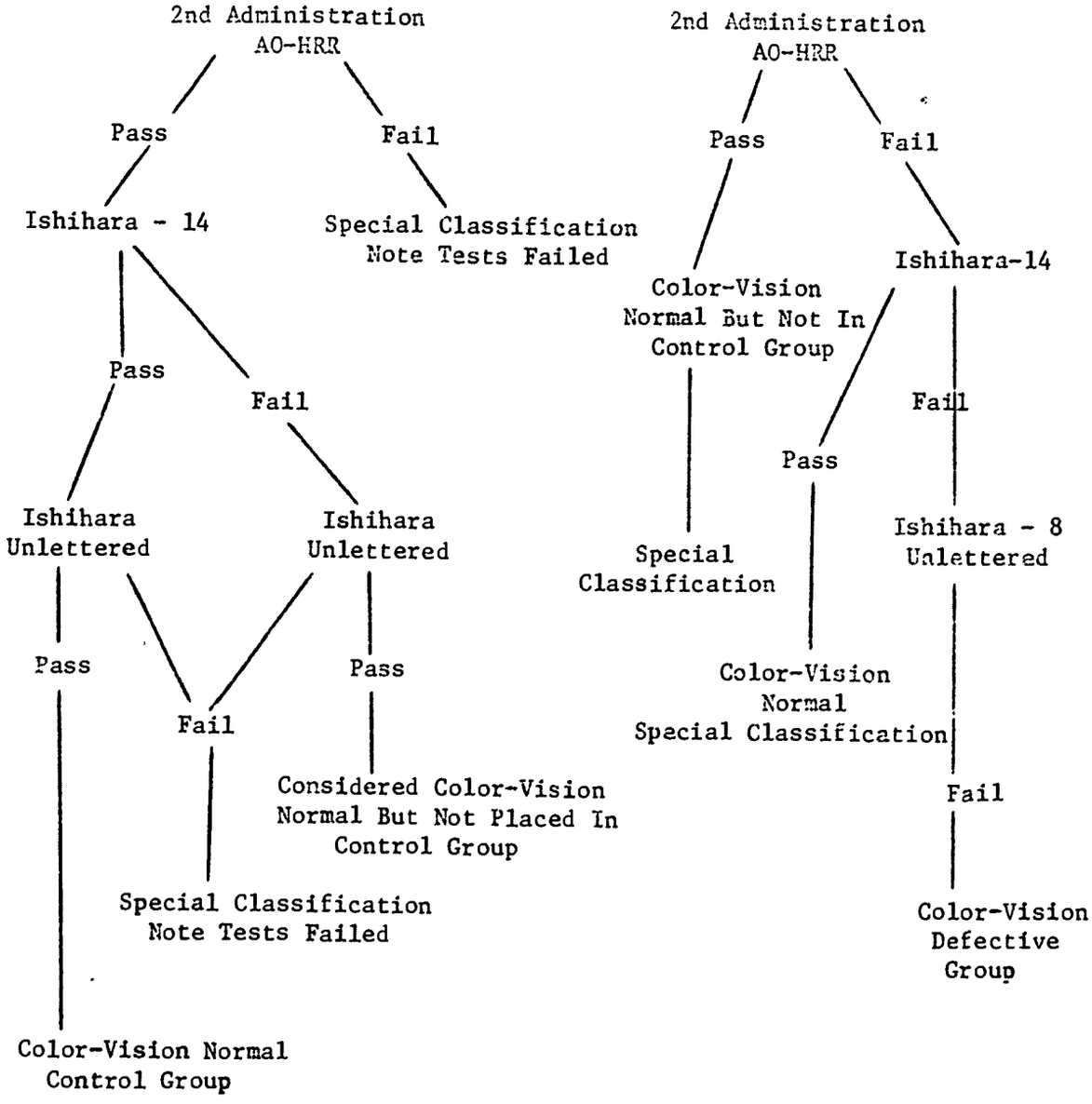
Phase I of Color-Vision Testing Initial Testing & Screening - 1st Administration of AO-HRR



APPENDIX X

Phase II 2nd Administration Of AO-HRR
And Ishihara Tests

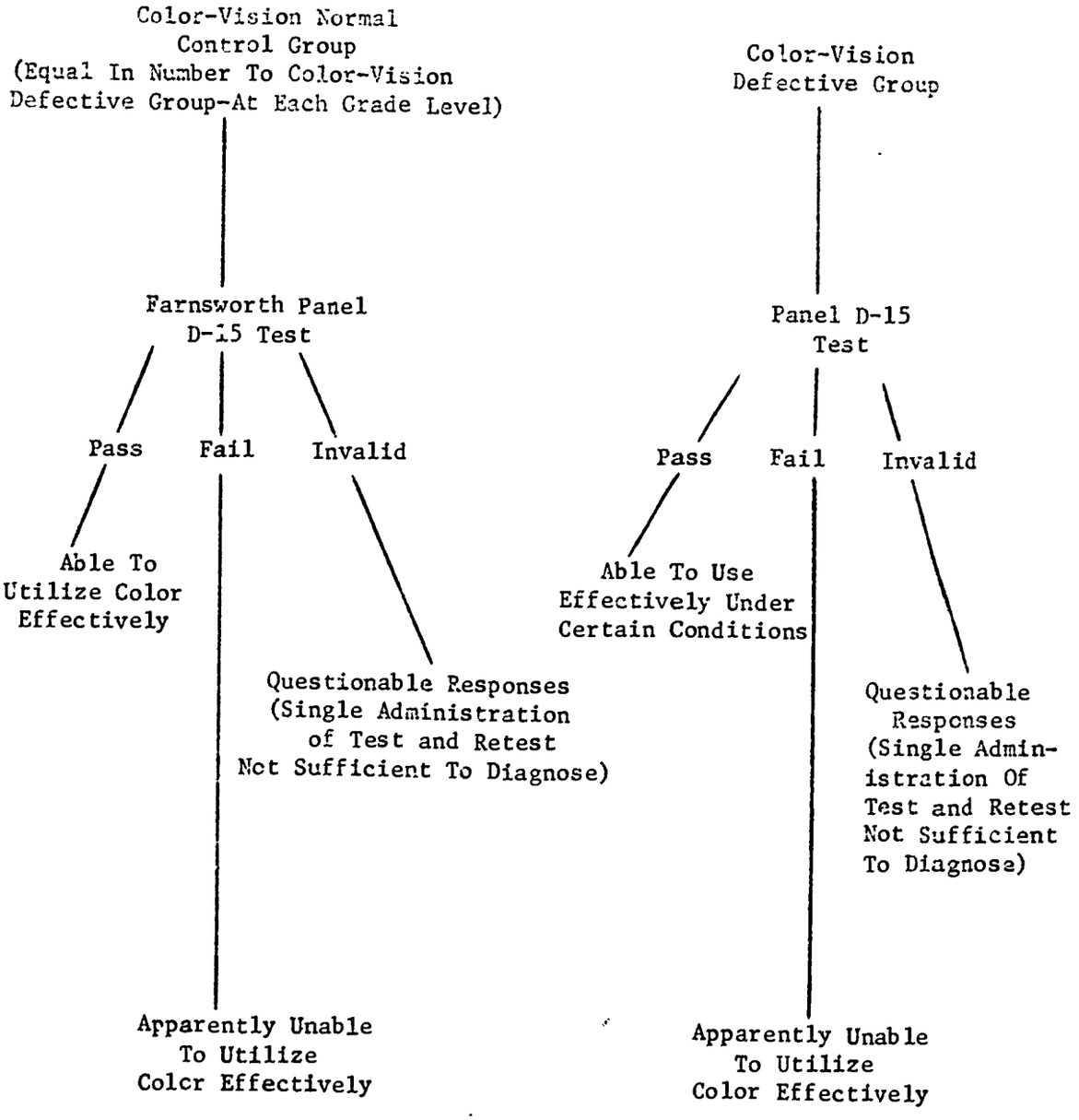
Phase II 2nd Administration Of AO-HRR
And Ishihara Tests



APPENDIX XI

Phase III Panel D-15 Test:
Control and Color-Vision Defective Groups

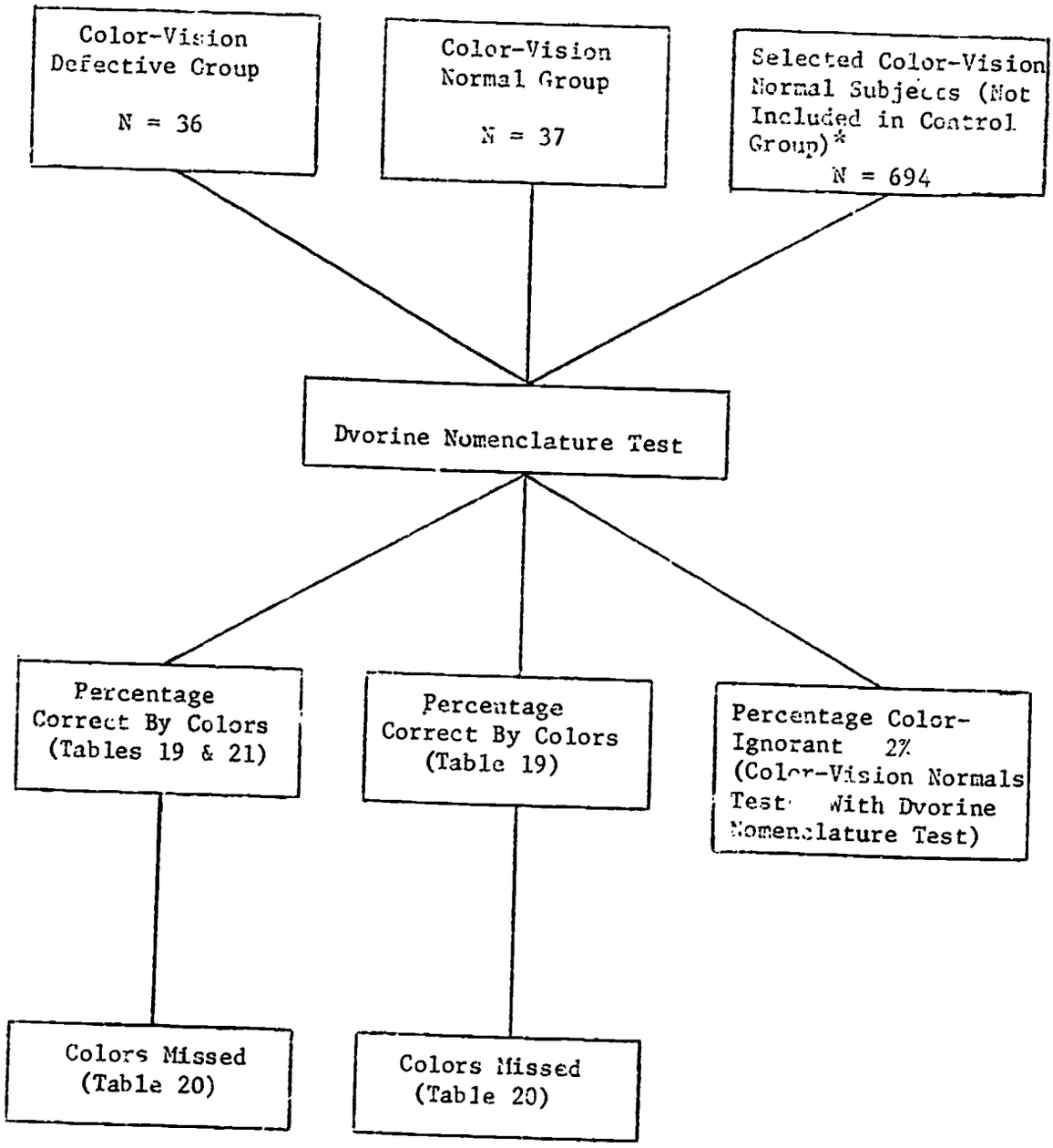
Phase III Panel D-15 Test:
Control And Color-Vision Defective Groups



APPENDIX XII

Phase IV -- Dvorine Nomenclature Test
Control Group, Color-Vision Defective Group
And Other Selected Subjects

Phase IV -- Dvorine Nomenclature Test
Control Group, Color-Vision Defective Group
And Other Selected Subjects



*Includes some Group 5 Subjects